

Region C Water Planning Group

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Cooksey Communications, Inc.

Introduction

In 1997, the 75th Texas Legislature passed Senate Bill One, legislation designed to address Texas water issues. With the passage of Senate Bill One, the legislature put in place a grass-roots regional planning process to plan for the water needs of all Texans in the next century. To implement this planning process, the Texas Water Development Board has created 16 regional water planning groups across the state and established regulations governing regional planning efforts.

This report gives the results of the planning process for Region C, one of the regions created to implement Senate Bill One. Figure I-1 is a map of Region C, which covers all or part of 16 counties in North Central Texas. As Figure I-1 shows, Region C includes all of Cooke, Grayson, Fannin, Jack, Wise, Denton, Collin, Parker, Tarrant, Dallas, Rockwall, Kaufman, Ellis, Navarro, and Freestone Counties and the part of Henderson County that is in the Trinity Basin.

The regional water planning groups created pursuant to Senate Bill One are in charge of the regional planning process⁽¹⁾. TWDB regulations require each regional planning group to include representatives of 11 designated interest groups. Table I-1 shows the members of the Region C water planning group and the interests they represent. The Region C water planning group hired a team of consultants to conduct technical analyses and prepare the regional water plan under the supervision of the planning group. The consulting team included Freese and Nichols, Inc., Alan Plummer Associates, Inc., Chiang, Patel, and Yerby, Inc., and Cooksey Communications, Inc.

Texas Water Development Board planning guidelines require each regional water plan to include seven tasks, which are addressed in the seven sections of this report. The tasks are:

1. Description of Region C
2. Population and Water Demand Projections
3. Analysis of Water Supply Currently Available to Region C

⁽¹⁾Numbers in parentheses match references listed in Appendix A.

4. Comparison of Current Water Supply and Projected Water Demand
5. Evaluation and Selection of Water Management Strategies
6. Regulatory, Legislative, Administrative, and Other Recommendations
7. Plan Approval Process and Public Participation

The report also includes a number of appendices providing more detailed information on the planning efforts.

**Table I-1
Members of the Region C Water Planning Group**

Member	Affiliation	Interest
Terrace W. Stewart, Chairman	Dallas Water Utilities	Municipalities
James Parks, Vice-Chairman	North Texas Municipal Water District	Water Districts
Roy F. Eaton, Secretary	Wise County Messenger	Small Business
Brad Barnes	Rancher	Agricultural
A. Leroy Burch	Retired	Industries
Jerry W. Chapman	Greater Texoma Utility Authority	Water Districts
Dale Fisseler	City of Fort Worth	Municipalities
Howard Martin	City of Denton	Municipalities
Jim McCarter	Navarro Mills WSC	Water Utilities
Elaine Petrus	Streams and Valleys	Environmental
Paul Phillips	City of Weatherford	Municipalities
Irvin M. Rice	Retired	Public
Robert O. Scott	Tarrant Coalition for Environmental Awareness	Environmental
George Shannon	Tarrant Regional Water District	Water Districts
Connie Standridge	Winkler WSC	Water Utilities
Danny Vance	Trinity River Authority	River Authorities
Judge Tom Vandergriff	Tarrant County	Counties
Mary E. Vogelson	League of Women Voters	Public
Paul Zweiacker	Texas Utilities	Electric Generating Utilities

1. Description of Region C

Table 1.1 shows historical populations from 1900 through 1998 for the counties in Region C^(2, 3). Table 1.1 also shows the estimated total population for the region for the same period, including only the portion of Henderson County in Region C. Figure 1.1 is a plot of the historical population for Region C. During the 1900s, the population of Region C has grown from 588,706 in 1900 to an estimated 4,779,210 in 1998. Since 1940, the region's population has increased at a compounded rate of 2.6 percent per year. The increase of 700,920 people (17.2 percent) from 1990 through 1998 indicates that the area is still growing rapidly.

As of 1998, Region C included 24.4 percent of Texas' total population. The two most populous counties in Region C, Dallas and Tarrant, have 70.6 percent of the region's population. Collin, Denton, Grayson, and Ellis Counties also have 1998 populations over 100,000 people. Table 1.2 lists the 38 cities in Region C with an estimated 1998 population of more than 20,000. These cities include 80.5 percent of the 1998 population of the region.

1.1 Economic Activity in Region C

Region C includes most of the Dallas and Fort Worth-Arlington metropolitan statistical areas (MSAs). The largest employment sector in the Dallas MSA is the service industry, followed by trade, manufacturing and government. The Fort Worth-Arlington MSA's largest employment sectors are service, trade, and manufacturing. The Dallas and Fort Worth-Arlington MSAs have experienced strong economic growth in the 1990s⁽²⁾.

Table 1.3 lists 1995 payrolls for Region C by county and economic sector⁽⁴⁾. (1995 is the most recent year for which data were available when this report was written). Payroll and employment in Region C are concentrated in the central urban counties of Dallas and Tarrant, which have 86.6 percent of the region's total payroll and 84.7 percent of the employment. (Economic activity is more concentrated than population because many workers commute from outlying counties to work in Dallas and Tarrant Counties.) The largest business sectors in Region C in terms of payroll are services and manufacturing, which account for a combined 51.3 percent of the region's total payroll.

**Table 1.1
Historical Population for Region C Counties**

County	Historical Population ^a										
	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	1998
Collin	50,587	49,021	49,609	46,180	47,190	41,692	41,247	66,920	144,490	264,036	416,620
Cooke	27,494	26,603	25,667	24,136	24,909	22,146	22,560	23,471	27,656	30,777	34,200
Dallas	82,726	135,748	210,551	325,691	398,564	614,799	951,527	1,327,321	1,556,549	1,852,810	2,032,171
Denton	28,318	31,258	35,355	32,822	33,658	41,365	47,432	75,633	143,126	273,525	382,389
Ellis	50,059	53,629	55,700	53,936	47,733	45,645	43,395	46,638	59,743	85,167	102,200
Fannin	51,793	44,801	48,186	41,163	41,064	31,253	23,880	22,705	24,285	24,804	28,015
Freestone	18,910	20,557	23,264	22,589	21,138	15,696	12,525	11,116	14,830	15,818	17,872
Grayson	63,661	65,996	74,165	65,843	69,499	70,467	73,043	83,225	89,796	95,021	104,202
Henderson ^b	14,338	14,454	20,339	21,959	22,848	16,807	15,642	19,003	30,591	42,034	49,515
Jack	10,224	11,817	9,863	9,046	10,206	7,755	7,418	6,711	7,408	6,981	7,730
Kaufman	33,376	35,323	41,276	40,905	38,308	31,170	29,931	32,392	39,015	52,220	63,583
Navarro	43,374	47,070	50,624	60,507	51,308	39,916	34,423	31,150	35,323	39,926	43,082
Parker	25,823	26,331	23,382	18,759	20,482	24,528	22,880	33,888	44,609	64,785	77,525
Rockwall	8,531	8,072	8,591	7,658	7,051	6,156	5,878	7,046	14,528	25,604	37,863
Tarrant	52,376	108,572	152,800	197,553	225,521	361,253	538,495	716,317	860,880	1,170,103	1,340,037
Wise	27,116	26,450	23,363	19,178	19,074	16,141	17,021	19,687	26,575	34,679	42,206
Region C Total	588,706	705,702	852,735	987,925	1,078,553	1,386,789	1,887,297	2,523,223	3,119,404	4,078,290	4,779,210
% Increase		19.9%	20.8%	15.9%	9.2%	28.6%	36.1%	33.7%	23.6%	30.7%	17.2%
Henderson (Total)	19,970	20,131	28,327	30,583	31,822	23,408	21,786	26,466	42,606	58,543	68,962

Notes: a. Population data through 1990 are from *The Texas Almanac* ⁽²⁾. Data for 1998 are from the Texas State Data Center ⁽³⁾.

b. The Henderson County population in Region C is assumed to be 71.8% of the total Henderson County population based on the ratio of TWDB's Region C Henderson County population to total Henderson County population in 1990.

Figure 1.1
Historical Population for Region C

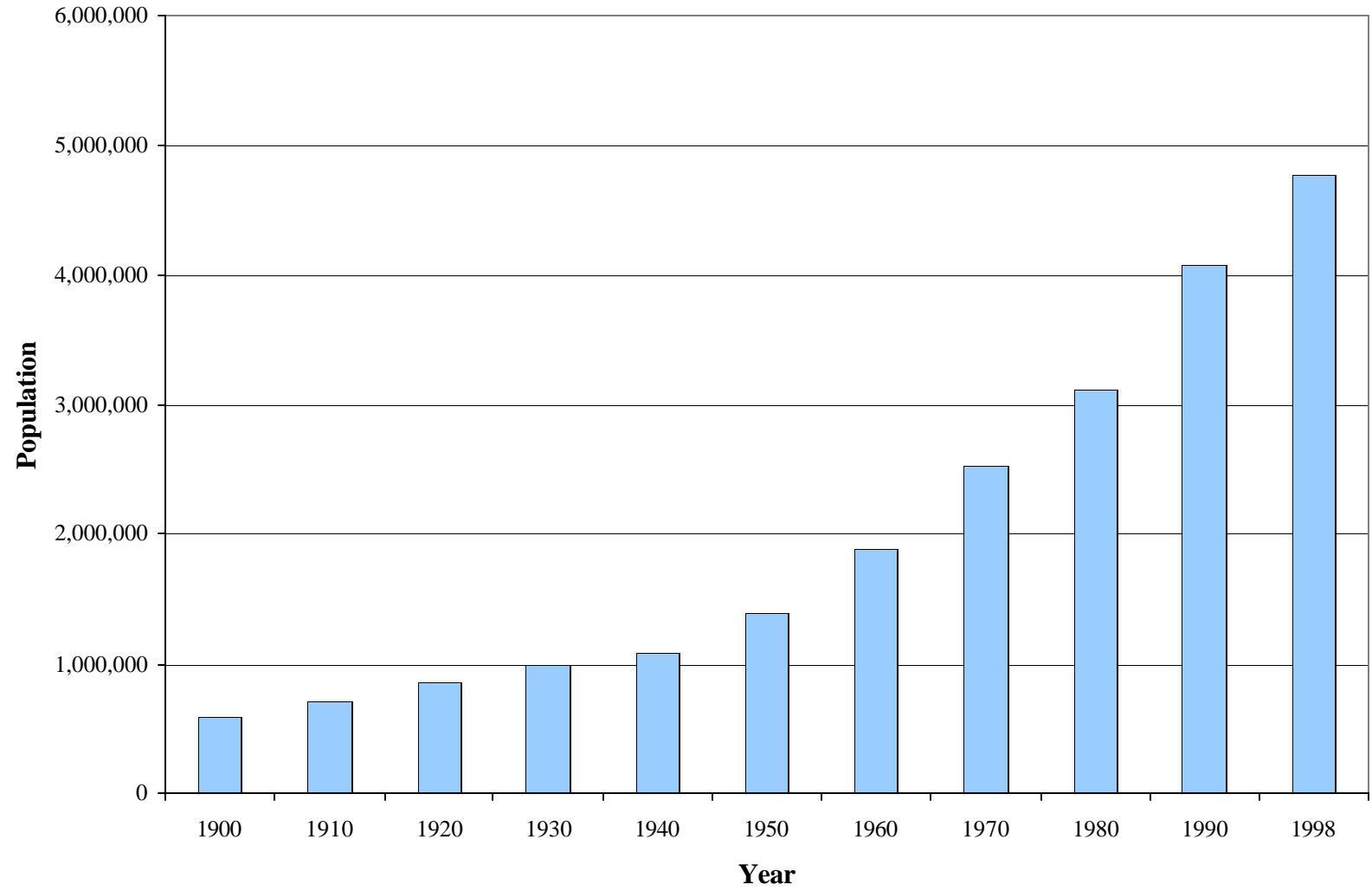


Table 1.2
Cities in Region C with Estimated 1998 Population Greater than 20,000

City	Estimated 1998 Population	County(ies)
Dallas	1,085,614	Dallas, Collin, Denton, Kaufman, Rockwall
Fort Worth	489,277	Tarrant, Denton, Johnson
Arlington	301,991	Tarrant
Plano	198,186	Collin, Denton
Garland	193,475	Dallas, Collin
Irving	175,983	Dallas
Mesquite	114,699	Dallas
Grand Prairie	113,672	Dallas, Tarrant, Ellis
Carrollton	100,950	Dallas, Denton
Richardson	90,798	Dallas, Collin
Denton	78,028	Denton
Lewisville	67,180	Denton, Dallas
North Richland Hills	54,688	Tarrant
Bedford	48,813	Tarrant
Euless	46,632	Tarrant
Flower Mound	40,291	Denton
Hurst	39,274	Tarrant
Grapevine	38,528	Tarrant, Dallas
Rowlett	38,203	Dallas, Rockwall
Duncanville	36,364	Dallas
Haltom City	36,177	Tarrant
DeSoto	35,615	Dallas
McKinney	34,979	Collin
Sherman	34,395	Grayson
Allen	32,501	Collin
The Colony	28,956	Denton
Cedar Hill	28,100	Dallas, Ellis
Coppell	27,625	Dallas
Lancaster	27,147	Dallas
Farmers Branch	26,227	Dallas
Corsicana	24,450	Navarro
Benbrook	22,902	Tarrant
University Park	22,872	Dallas
Watauga	22,682	Tarrant
Mansfield	22,679	Tarrant, Johnson, Ellis
Denison	22,425	Grayson
Keller	21,580	Tarrant
Waxahachie	20,961	Ellis
Total	3,844,919	

Note: Data are from the Texas State Data Center ⁽³⁾.

Table 1.3
1995 County Payroll by Category (\$1,000)

	Collin	Cooke	Dallas	Denton	Ellis	Fannin	Freestone	Grayson
Agriculture	\$20,043	\$390	\$119,995	\$17,010	\$1,358	\$445	\$0	\$2,183
Mining	\$123,084	\$4,246	\$781,095	\$3,099	\$0	\$0	\$0	\$2,763
Construction	\$117,637	\$3,390	\$1,592,815	\$117,294	\$23,278	\$2,481	\$0	\$37,813
Manufacturing	\$969,379	\$67,564	\$6,493,130	\$421,954	\$249,571	\$31,169	\$4,511	\$328,743
Transportation & Public Utilities	\$126,670	\$8,190	\$4,384,175	\$114,607	\$34,217	\$5,802	\$38,253	\$30,825
Wholesale Trade	\$254,111	\$8,531	\$4,775,360	\$221,180	\$23,175	\$7,864	\$1,619	\$27,759
Retail Trade	\$414,326	\$29,546	\$3,576,408	\$527,094	\$51,335	\$12,216	\$9,727	\$113,583
Financial, Insurance, & Real Estate	\$181,856	\$6,548	\$4,721,015	\$80,983	\$17,742	\$9,493	\$2,419	\$42,944
Services	\$1,147,326	\$32,914	\$12,678,321	\$438,972	\$106,978	\$29,771	\$7,080	\$196,521
Unclassified	\$1,063	\$119	\$12,914	\$1,283	\$0	\$57	\$0	\$236
Not Categorized	\$0	\$0	\$0	\$0	\$1,786	\$0	\$18,510	\$0
Total Payroll	\$3,355,495	\$161,438	\$39,135,228	\$1,943,476	\$509,440	\$99,298	\$82,119	\$783,370
Total Employees	104,583	8,896	1,256,339	79,040	22,722	5,100	3,007	33,597

	Henderson ^b	Jack	Kaufman	Navarro	Parker	Rockwall	Tarrant	Wise	Total
Agriculture	\$1,465	\$469	\$818	\$946	\$1,914	\$1,261	\$48,888	\$813	\$217,998
Mining	\$5,093	\$2,513	\$1,345	\$6,029	\$2,625	\$450	\$207,609	\$21,286	\$1,161,237
Construction	\$11,107	\$740	\$18,237	\$5,964	\$18,867	\$10,010	\$684,065	\$5,233	\$2,648,931
Manufacturing	\$32,720	\$0	\$97,018	\$50,426	\$49,888	\$28,744	\$3,516,851	\$27,688	\$12,369,356
Transportation & Public Utilities	\$14,262	\$2,166	\$9,788	\$11,953	\$8,207	\$12,503	\$1,323,903	\$15,369	\$6,140,890
Wholesale Trade	\$7,469	\$2,384	\$16,130	\$18,640	\$17,771	\$10,239	\$1,149,130	\$6,846	\$6,548,208
Retail Trade	\$38,943	\$2,419	\$38,929	\$53,116	\$49,935	\$22,148	\$1,772,518	\$29,736	\$6,741,979
Financial, Insurance, & Real Estate	\$12,405	\$1,653	\$12,387	\$13,150	\$12,255	\$8,657	\$811,814	\$6,807	\$5,942,128
Services	\$50,393	\$3,388	\$89,897	\$60,270	\$68,573	\$31,618	\$3,685,348	\$26,926	\$18,654,296
Unclassified	\$74	\$0	\$218	\$219	\$282	\$103	\$5,532	\$128	\$22,228
Not Categorized	\$0	\$279	\$0	\$0	\$0	\$0	\$0	\$0	\$20,575
Total Payroll	\$173,931	\$16,011	\$284,767	\$220,713	\$230,317	\$125,733	\$13,205,658	\$140,832	\$60,467,826
Total Employees	10,318	945	14,024	11,711	12,091	6,510	514,017	6,848	2,089,748

Notes: a. Data are from U.S. Census 1995 economic data ⁽⁴⁾.
b. Data for Henderson County include the entire county.

1.2 Water-Related Physical Features in Region C

Most of Region C is in the upper portion of the Trinity Basin, with smaller parts in the Red, Brazos, Sulphur, and Sabine Basins. With the exception of the Red River Basin, the predominant flow of the streams is from northwest to southeast, as is true for most of Texas. The Red River itself flows west to east, forming the north border of Region C, and its major tributaries in Region C flow southwest to northeast. Figure I-1 shows the major streams in Region C, which include the Brazos River, Clear Fork Trinity River, West Fork Trinity River, Elm Fork Trinity River, East Fork Trinity River, Trinity River, Red River, and numerous tributaries of the Trinity River. According to the Texas Parks and Wildlife Department, there are 324 streams of various sizes in Region C.

Figure 1.2 shows the average annual precipitation for Region C. Precipitation increases west to east from slightly more than 30 inches per year in western Jack County to more than 44 inches per year in the northeast corner of Fannin County ⁽⁵⁾. Figure 1.3 shows average annual runoff, which follows a similar pattern of increasing from the west to the east ⁽⁵⁾. (It is interesting to note that the percentage of rainfall that becomes runoff increases dramatically from west to east across Region C. While the average rainfall is about 1.5 times as great in the east as in the west, the runoff is almost 5 times as great in the east as in the west.) Figure 1.4 shows gross reservoir evaporation in Region C, which is higher to the west ⁽⁶⁾. (Gross reservoir evaporation indicates the amount lost to evaporation from the surface of a reservoir.) The rate of evaporation from a reservoir surface exceeds rainfall throughout Region C, but the margin is much greater in the western part of the region than in the east. The patterns of rainfall, runoff, and evaporation result in more abundant water supplies in the eastern part of Region C than in the west.

Figure 1.5 shows the variations in annual streamflow for five U.S. Geological Survey (USGS) streamflow gages in Region C ⁽⁷⁾. The four gages on tributaries have watersheds with limited development and show the natural variation of streamflows in this region. The Trinity River near Rosser gage is on the main stem of the Trinity River downstream from the Dallas-Fort Worth area. At this location, natural flow patterns have been substantially altered by reservoir development and by return flows of treated wastewater. Figure 1.6 shows seasonal patterns of median streamflows for the same five gages ⁽⁷⁾. Return flows from the Dallas-Fort Worth area

Figure 1.2
Average Annual Precipitation

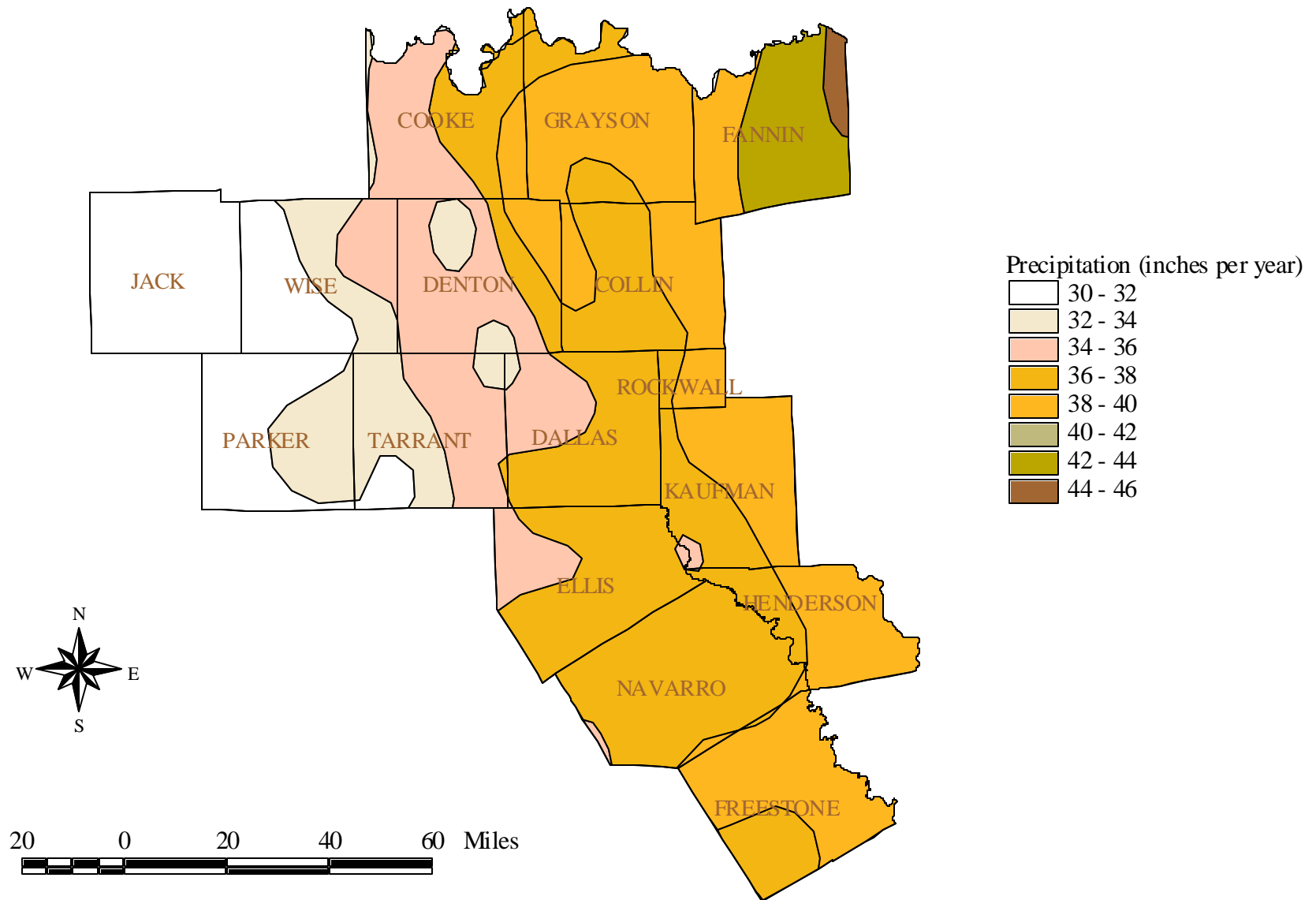


Figure 1.3
Average Annual Runoff

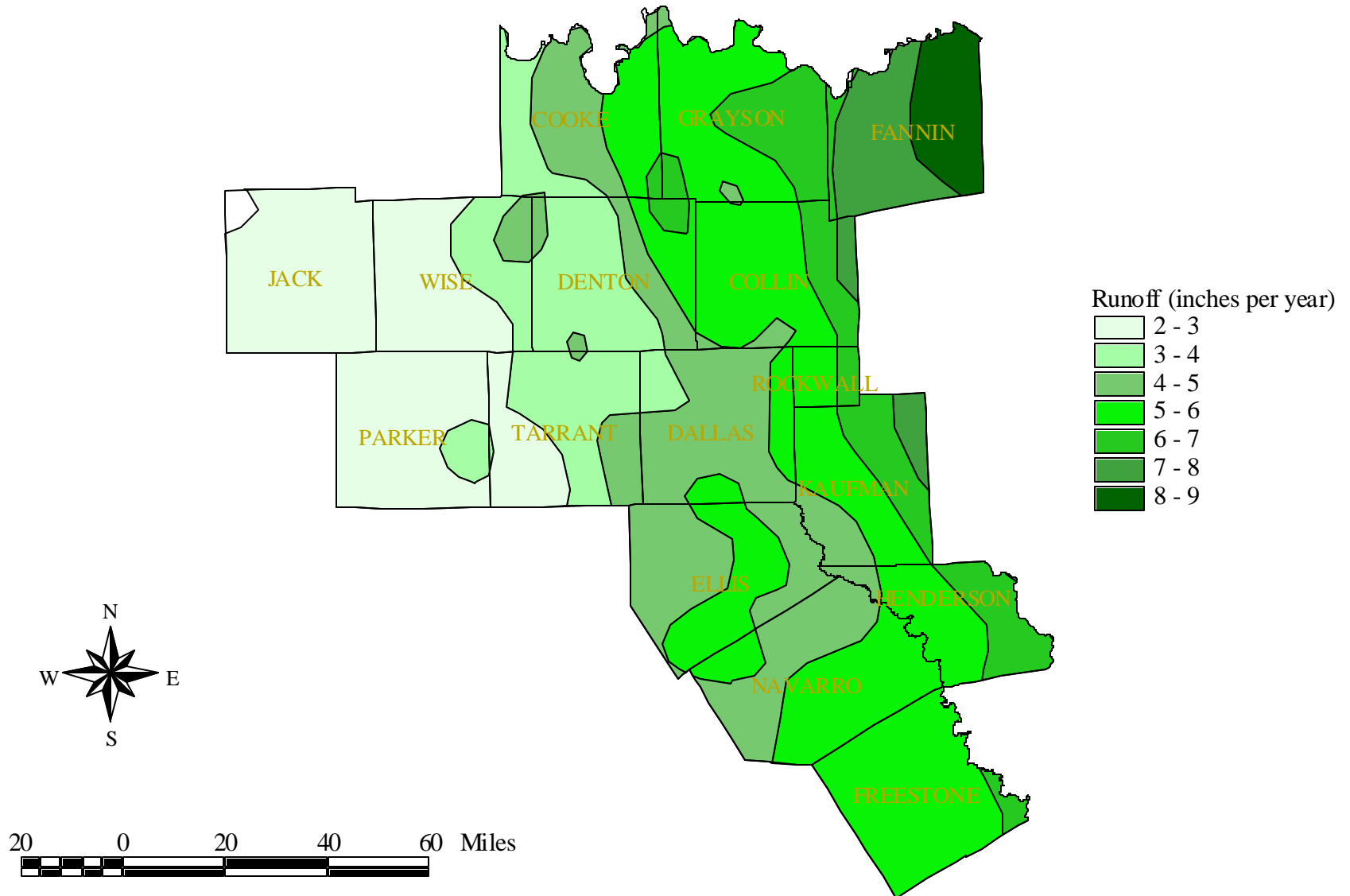
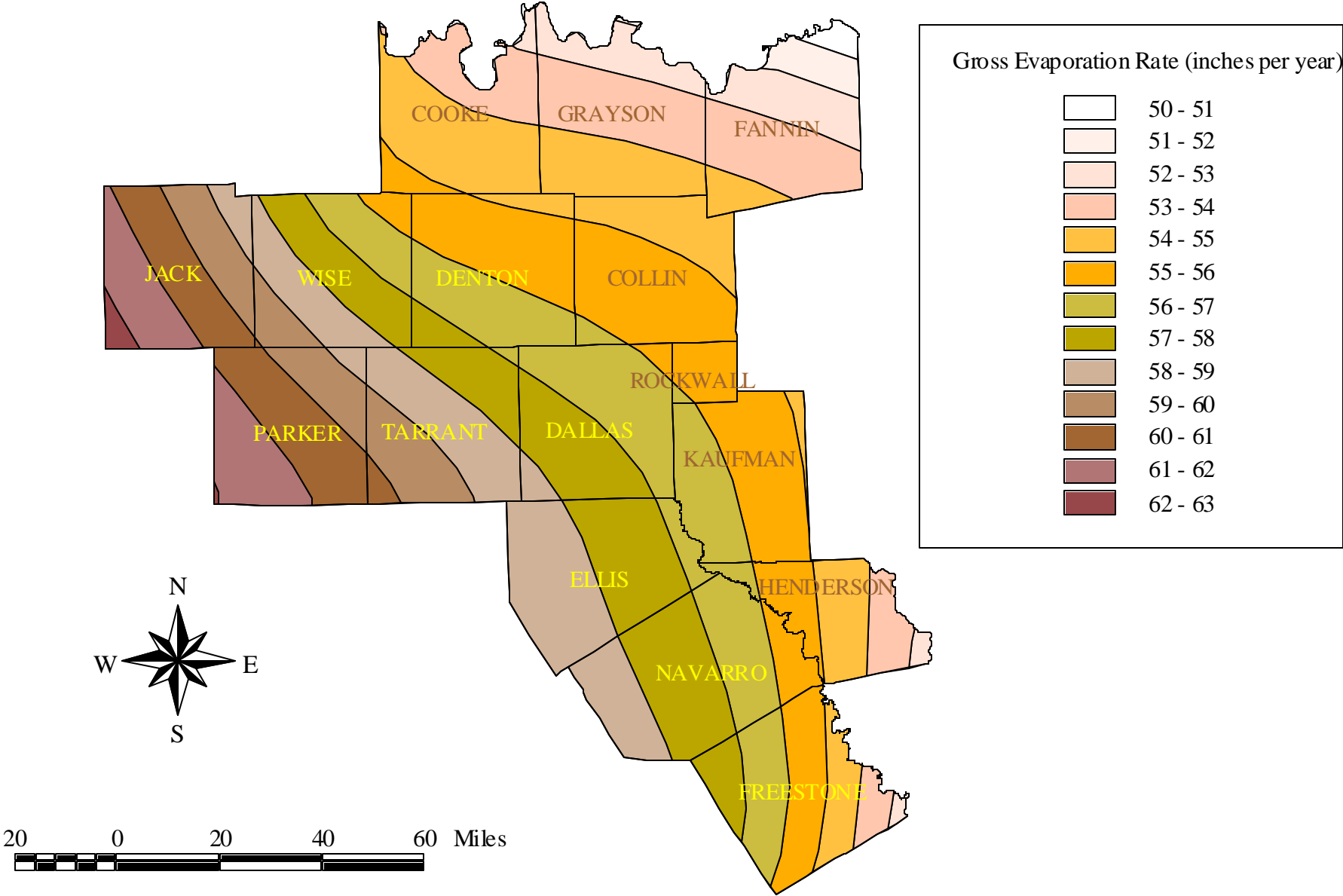


Figure 1.4
Average Annual Gross Evaporation



reduce seasonal variations in flow at the Rosser gage by significantly increasing summer flows compared to natural conditions.

Table 1.4 lists the 34 reservoirs in Region C with conservation storage over 5,000 acre-feet, all of which are shown in Figure I-1. These reservoirs and others outside of Region C provide most of the region's water supply. Reservoirs are necessary to provide a reliable surface water supply in this part of the state because of the wide variations in natural streamflow. Reservoir storage serves to capture high flows when they are available and save them for use during times of normal or low flow.

Figure 1.7 shows major aquifers in Region C, and Figure 1.8 shows minor aquifers⁽⁸⁾. The most heavily used aquifer in Region C is the Trinity aquifer, which supplies most of the groundwater used in the region. The Carrizo-Wilcox aquifer also outcrops in Region C in Navarro, Freestone, and Henderson Counties. Minor aquifers in Region C include the Woodbine aquifer, the Nacatoch aquifer, and a small part of the Queen City aquifer.

1.3 Current Water Uses and Demand Centers in Region C

Table 1.5 shows the total water use by county in Region C from 1980 through 1997, the most recent year for which data are available⁽⁹⁾. Water use in Region C has increased significantly since 1980, primarily in response to increasing population and municipal use. The historical record shows years of high use, including 1988 and 1996. 1998 and 2000 are not included in Table 1.5 because data have not yet been finalized, but preliminary figures show that 1998 and 2000 were also high use years. High use years are associated with dry weather, which causes higher municipal use due to increased outdoor water use (lawn watering). Table 1.6 shows water use for the same period by Texas Water Development Board use category. Figure 1.9 is a graph of the historical water use for Region C by category. Table 1.6 also shows statewide water use by category for 1997 and Region C use as a percent of statewide use. It is interesting to note that Region C, with 24.4 percent of Texas' population, had only 7.2 percent of the state's water use in 1997. This is primarily because Region C has very limited water use for irrigation, while irrigation use is more than 60 percent of total use for the state as a whole.

Table 1.7 shows the use by category by county in 1997, the most recent year for which water use data are available. About 85 percent of the current water use in Region C is for municipal supply, with manufacturing use as the second largest category, followed by steam electric power generation. Irrigation, mining, and livestock are relatively minor uses of water in Region C. The

**Table 1.4
Major Reservoirs in Region C (Over 5,000 Acre-Feet of Conservation Storage)**

Reservoir	Basin	Stream	County(ies)	Permitted Conservation Storage (Acre-Feet)	Owner	Water Right Holder(s)
Moss	Red	Fish Creek	Cooke	23,210	Gainesville	Gainesville
Texoma	Red	Red River	Grayson, Cooke	2,733,000	Corps of Engineers	Red River Authority, Greater Texoma UA, Denison, North Texas MWD, TXU Electric
Randell	Red	Unnamed Trib. Shawnee Creek	Grayson	5,400	Denison	Denison
Valley	Red	Sand Creek	Fannin, Grayson	15,000	TXU Electric	TXU Electric
Bonham	Red	Timber Creek	Fannin	13,000	Bonham MWA	Bonham
Coffee Mill	Red	Coffee Mill Creek	Fannin	8,000	USDA	U.S. Department of Agriculture
Kiowa	Trinity	Indian Creek	Cooke	7,000	Lake Kiowa POA Inc.	Lake Kiowa Property Owners Association, Inc.
Ray Roberts	Trinity	Elm Fork Trinity River	Denton, Cooke, Grayson	799,600	Corps of Engineers	Dallas and Denton
Lost Creek	Trinity	Lost Creek	Jack	11,961	Jacksboro	Jacksboro
Bridgeport	Trinity	West Fork Trinity River	Wise, Jack	387,000	TRWD	Tarrant Regional Water District
Lewisville	Trinity	Elm Fork Trinity River	Denton	618,400	Corps of Engineers	Dallas and Denton
Lavon	Trinity	East Fork Trinity River	Collin	380,000	Corps of Engineers	North Texas MWD
Weatherford	Trinity	Clear Fork Trinity River	Parker	19,470	Weatherford	Weatherford
Grapevine	Trinity	Denton Creek	Tarrant, Denton	161,250	Corps of Engineers	Park Cities MUD, Dallas, Grapevine
Eagle Mountain	Trinity	West Fork Trinity River	Tarrant, Wise	210,000	TRWD	Tarrant Regional Water District
Worth	Trinity	West Fork Trinity River	Tarrant	38,124	Fort Worth	Fort Worth
Benbrook	Trinity	Clear Fork Trinity River	Tarrant	88,250	Corps of Engineers	Tarrant Regional Water District, Benbrook WSA
Arlington	Trinity	Village Creek	Tarrant	45,710	Arlington	Arlington and TXU Electric
Joe Pool	Trinity	Mountain Creek	Dallas, Tarrant	176,900	Corps of Engineers	Trinity River Authority
Mountain Creek	Trinity	Mountain Creek	Dallas	22,840	TXU Electric	TXU Electric
North	Trinity	South Fork Grapevine Creek	Dallas	17,100	TXU Electric	TXU Electric
White Rock	Trinity	White Rock Creek	Dallas	21,345	Dallas	Dallas

Table 1.4, Continued

Reservoir	Basin	Stream	County(ies)	Permitted Conservation Storage (Acre-Feet)	Owner	Water Right Holder(s)
Ray Hubbard	Trinity	Elm Fork Trinity River	Dallas, Kaufman, Rockwall	490,000	Dallas	Dallas
Terrell	Trinity	Muddy Cedar Creek	Kaufman	8,712	Terrell	Terrell
Bardwell	Trinity	Waxahachie Creek	Ellis	54,900	Corps of Engineers	Trinity River Authority
Waxahachie	Trinity	Waxahachie Creek	Ellis	13,500	Ellis Co. WCID#1	Ellis Co. WCID#1
Cedar Creek	Trinity	Cedar Creek	Henderson, Kaufman	678,900	TRWD	Tarrant Regional Water District
Forest Grove	Trinity	Caney Creek	Henderson	20,038	TXU Electric	TXU Electric
Trinidad	Trinity	Off-channel	Henderson	6,200	TXU Electric	TXU Electric
Navarro Mills	Trinity	Richland Creek	Navarro	63,300	Corps of Engineers	Trinity River Authority
Halbert	Trinity	Elm Creek	Navarro	7,357	Corsicana	Corsicana
Richland-Chambers	Trinity	Richland Creek	Freestone, Navarro	1,135,000	TRWD	Tarrant Regional Water District
Fairfield	Trinity	Big Brown Creek	Freestone	50,600	TXU Electric	TXU Electric
Mineral Wells	Brazos	Rock Creek	Parker	7,065	Mineral Wells	Mineral Wells

Note: Data are from TNRCC water rights list ⁽¹⁰⁾ and other sources.

Figure 1.7
Major Aquifers in Region C Counties

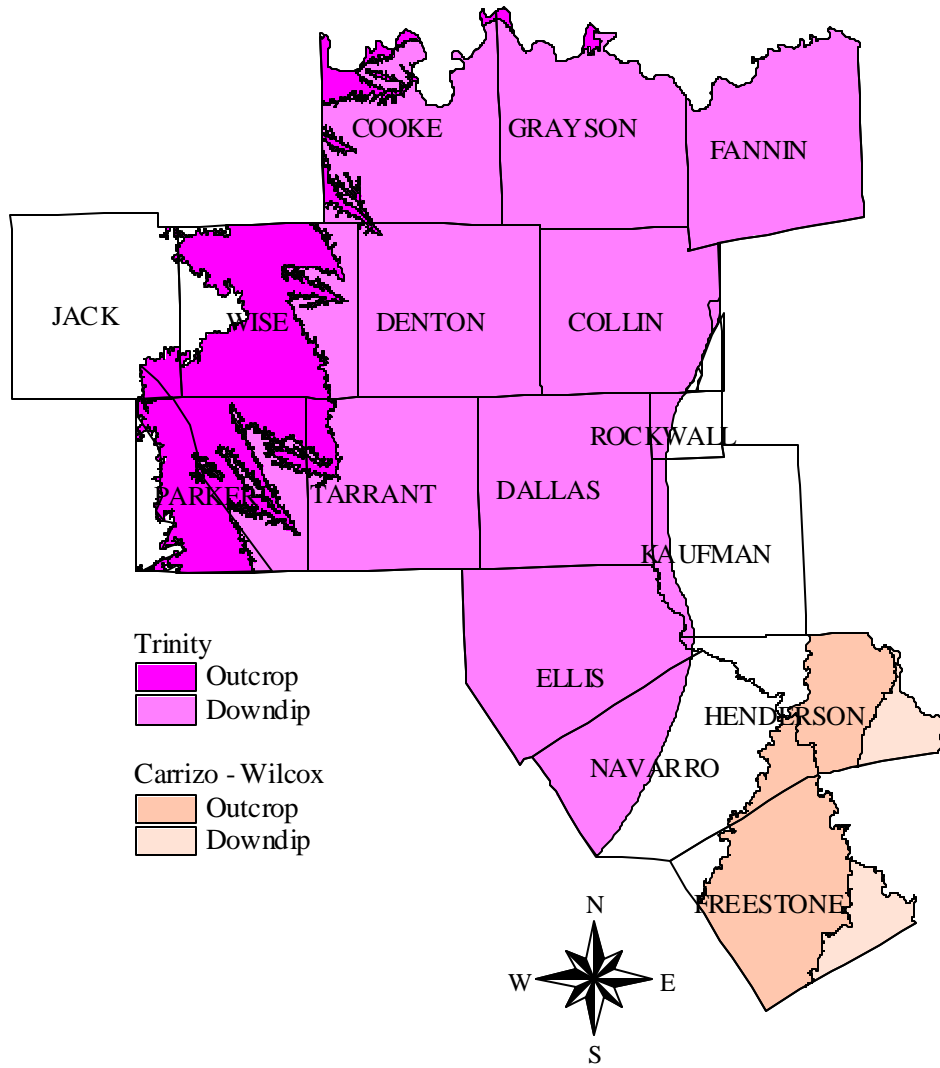
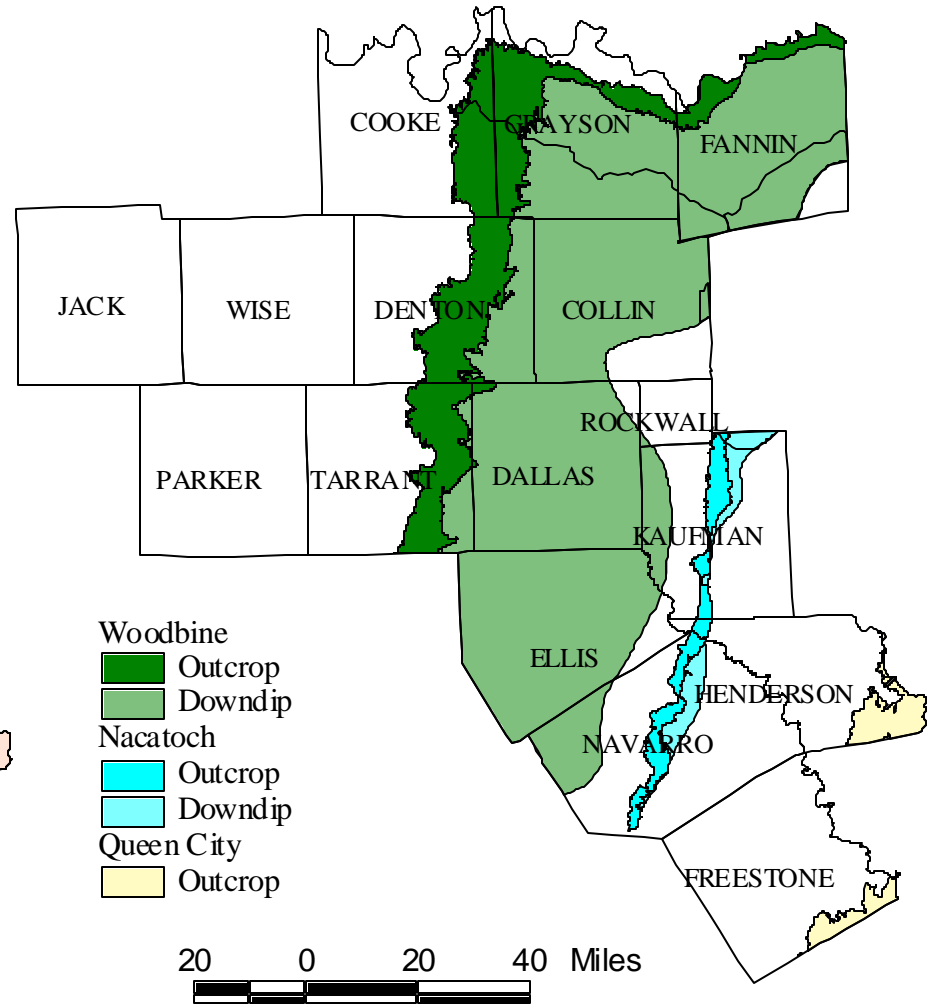


Figure 1.8
Minor Aquifers in Region C Counties



Note:
Outcrop is the area of the formation at the surface.
Downdip is the area of the formation below the surface.

**Table 1.5
Historical Total Water Use by County in Region C (Acre-Feet)**

County	Year							
	1980	1984	1985	1986	1987	1988	1989	1990
Collin	31,259	38,801	44,704	43,392	50,732	54,679	59,709	62,349
Cooke	7,286	7,673	7,623	7,857	7,057	7,600	6,841	7,406
Dallas	421,283	459,725	483,660	468,569	473,595	514,423	466,565	483,283
Denton	27,761	35,925	38,172	40,176	43,089	44,753	46,826	49,876
Ellis	12,452	17,493	18,444	14,843	15,543	18,540	18,683	18,967
Fannin	25,080	14,209	15,115	12,184	14,202	15,532	11,633	13,133
Freestone	18,846	21,447	18,120	19,962	18,317	22,028	18,729	17,155
Grayson	27,877	22,534	26,110	23,215	22,431	24,370	24,020	23,150
Henderson ^b	9,307	11,800	11,832	10,427	10,416	11,858	10,077	9,615
Jack	2,007	2,125	2,291	2,286	2,156	2,090	2,063	2,071
Kaufman	8,234	9,815	9,642	9,302	9,604	9,162	9,857	10,008
Navarro	9,152	9,790	8,811	8,051	8,289	8,801	7,968	9,234
Parker	11,179	8,732	10,729	10,733	10,500	10,698	10,854	11,236
Rockwall	2,696	4,418	4,588	4,751	4,362	5,089	4,319	5,273
Tarrant	241,850	239,252	248,695	252,954	261,305	277,871	267,645	285,033
Wise	15,895	12,402	12,149	15,032	15,930	16,323	12,355	15,219
Total	872,164	916,141	960,685	943,734	967,528	1,043,817	978,144	1,023,008

County	Year						
	1991	1992	1993	1994	1995	1996	1997
Collin	60,461	62,689	72,759	71,803	82,827	89,230	94,231
Cooke	7,781	8,047	8,643	9,044	8,330	8,429	8,534
Dallas	450,134	463,009	492,243	449,483	492,531	505,423	495,381
Denton	48,647	49,303	54,527	52,063	58,738	65,075	66,880
Ellis	17,218	16,726	18,567	17,650	17,799	19,721	20,368
Fannin	9,175	9,339	13,353	12,664	14,965	17,515	13,760
Freestone	18,278	16,569	17,659	18,477	17,262	20,608	15,446
Grayson	22,379	21,274	23,892	23,943	26,958	29,152	27,810
Henderson ^b	7,920	7,583	8,875	7,915	9,217	10,653	9,791
Jack	2,407	2,380	2,434	2,624	2,319	3,337	2,399
Kaufman	9,741	9,530	11,657	10,819	10,770	10,653	10,245
Navarro	8,714	8,372	9,107	8,838	8,598	10,558	10,540
Parker	11,839	10,231	11,268	11,505	11,231	12,372	12,600

Table 1.5, Continued

County	Year						
	1991	1992	1993	1994	1995	1996	1997
Rockwall	5,076	4,718	5,462	5,495	6,212	6,566	6,437
Tarrant	264,569	248,053	274,763	264,769	273,657	291,406	283,626
Wise	15,094	14,605	20,869	23,594	24,396	25,688	30,608
Total	959,433	952,428	1,046,078	990,686	1,065,810	1,126,518	1,108,656

Notes: a. Data are from the Texas Water Development Board ⁽⁹⁾.
 b. Data for Henderson County include only the part of the county in Region C.

**Table 1.6
 Historical Water Use by Category in Region C (Acre -Feet)**

Year	Municipal	Manu- facturing	Steam Ele ctric	Irrigation	Mining	Livestock	Total
1980	666,010	100,657	53,009	23,993	10,114	18,381	872,164
1984	747,532	83,337	53,403	7,716	4,149	20,004	916,141
1985	789,077	81,998	51,661	12,404	6,386	19,159	960,685
1986	777,798	84,946	45,210	7,918	10,508	17,354	943,734
1987	801,530	79,017	48,503	7,817	13,437	17,224	967,528
1988	856,896	89,916	57,809	7,841	13,107	18,248	1,043,817
1989	801,595	97,859	47,433	6,640	7,153	17,464	978,144
1990	844,430	100,062	46,959	5,434	7,153	18,970	1,023,008
1991	798,811	89,141	36,951	4,441	10,948	19,141	959,433
1992	804,145	81,776	33,393	5,117	9,522	18,475	952,428
1993	879,038	81,043	39,175	10,749	17,478	18,595	1,046,078
1994	825,076	78,619	36,252	9,514	20,449	20,776	990,686
1995	897,591	76,036	40,321	11,693	20,324	19,845	1,065,810
1996	946,454	71,366	52,103	9,689	22,576	24,330	1,126,518
1997	942,004	79,048	35,673	10,451	23,283	18,197	1,108,656
State Total in 1997	3,429,392	1,521,336	325,890	9,529,808	246,673	338,004	15,391,103
% in Region C	27.5%	5.2%	10.9%	0.1%	9.4%	5.4%	7.2%

Note: Data are from the Texas Water Development Board ⁽⁹⁾.

Figure 1.9
Historical Water Use by Category in Region C

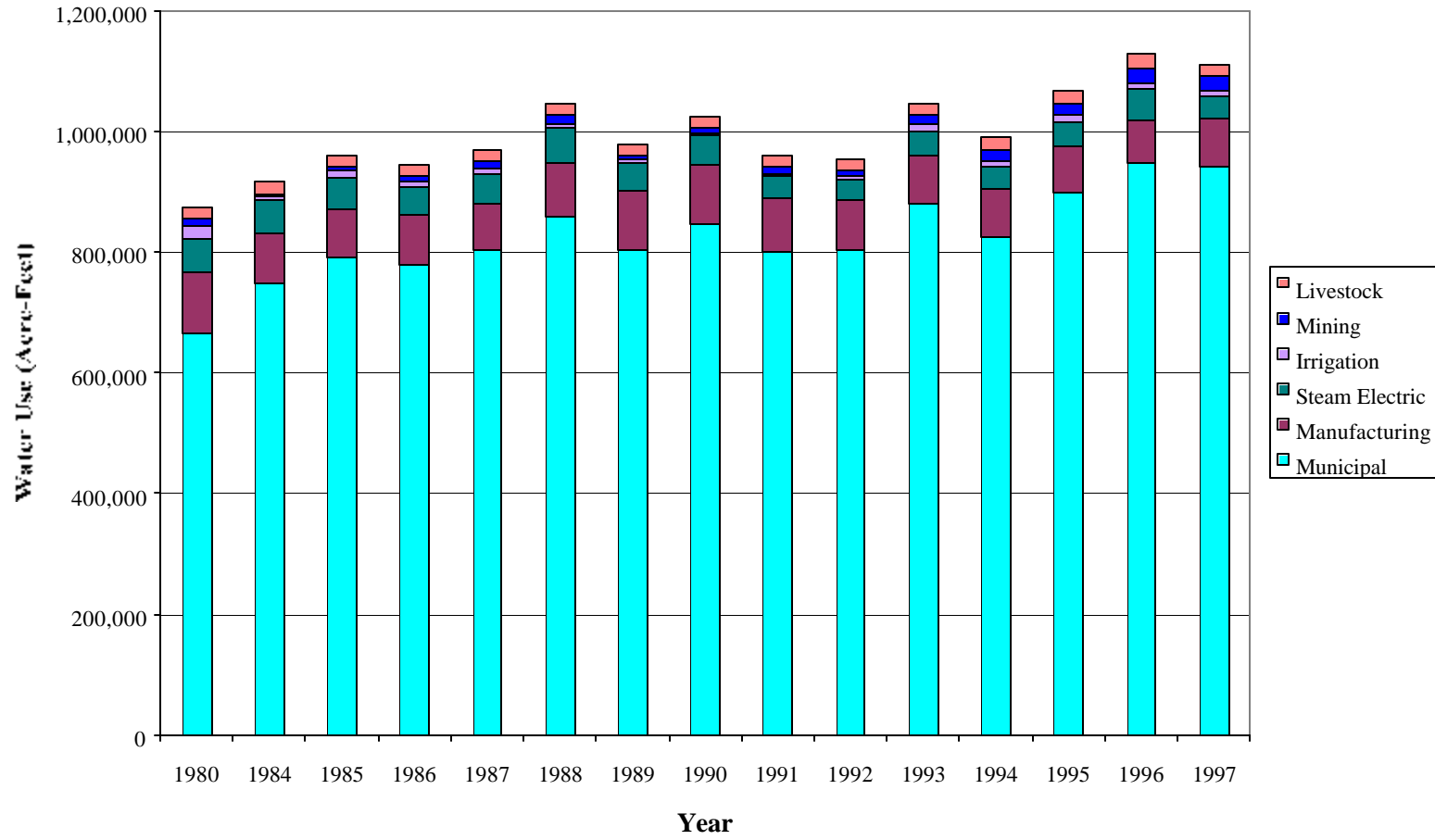


Table 1.7
1997 Water Use by Category by County (Acre-Feet)

County	Municipal	Manu- facturing	Steam Electric	Irrigation	Mining	Livestock	Total
Collin	89,214	1,832	1,661	93	341	1,090	94,231
Cooke	5,660	159	0	444	289	1,982	8,534
Dallas	450,099	28,575	11,802 ^b	1,317	2,990	598	495,381
Denton	63,525	886	122	472	139	1,736	66,880
Ellis	15,145	3,596	0	230	90	1,307	20,368
Fannin	4,060	345	4,967	3,038	161	1,189	13,760
Freestone	2,372	0	11,547	17	207	1,303	15,446
Grayson	15,670	6,547	0	3,512	1,058	1,023	27,810
Henderson ^b	7,413	93	797	29	631	828	9,791
Jack	1,048	0	0	4	433	914	2,399
Kaufman	8,282	641	0	135	75	1,112	10,245
Navarro	8,092	1,166	0	0	89	1,193	10,540
Parker	10,132	570	126	388	75	1,309	12,600
Rockwall	6,286	17	0	0	33	101	6,437
Tarrant	249,177	28,709	4,651	140	103	846	283,626
Wise	5,829	5,912	0	632	16,569	1,666	30,608
Total	942,004	79,048	35,673	10,451	23,283	18,197	1,108,656

Notes: a. Data are from the Texas Water Development Board ⁽⁹⁾.

b. Data for Henderson County include only the part of the county in Region C.

1997 water use in Tarrant and Dallas Counties was 70.3 percent of the total Region C use, and these two counties had 70.6 percent of the region's population in 1998.

In addition to the consumptive water uses discussed above, water is used for recreation and other purposes in Region C. Reservoirs for which records of visitors are maintained (primarily Corps of Engineers lakes with recreational facilities) draw millions of visitors each year in Region C. In addition, smaller lakes and streams in the region draw many visitors for fishing, boating, swimming, and other water-related recreational activities. Water in streams and lakes is also important to fish and wildlife in the region.

**Table 1.8
Historical Sources of Water Supply in Region C**

Year	Supply in Acre-Feet		
	Surface Water	Ground-water	Total
1980	779,799	92,365	872,164
1984	818,762	97,379	916,141
1985	858,607	102,078	960,685
1986	848,838	94,896	943,734
1987	871,038	96,490	967,528
1988	942,863	100,954	1,043,817
1989	884,663	93,481	978,144
1990	932,298	90,710	1,023,008
1991	874,846	84,587	959,433
1992	869,064	83,364	952,428
1993	959,840	86,238	1,046,078
1994	908,770	81,916	990,686
1995	981,168	84,642	1,065,810
1996	1,038,508	88,010	1,126,518
1997	1,020,639	88,017	1,108,656

Note: Data are from Texas Water Development Board ⁽⁹⁾.

1.4 Current Sources of Water Supply

Table 1.8 summarizes the total surface water and groundwater use in Region C from 1980 through 1997 ⁽⁹⁾, and Figure 1.10 shows the division of total water use between surface water and groundwater. Total water use has increased significantly since 1980, but groundwater use has actually decreased, with an increasing portion of the total supply coming from surface water. Since 1990, over 90 percent of the water use in Region C has been supplied by surface water. Table 1.9 shows the groundwater and surface water use by county and category for 1997, which is the most recent year for which data are available ⁽⁹⁾. Table 1.9 demonstrates some interesting points about water use in Region C:

- Although groundwater provides only 8 percent of the overall water use in Region C, it provides 63 percent of the irrigation use.
- Groundwater provides the majority of the total water use in Cooke and Grayson Counties and over 30 percent in Ellis, Fannin, Henderson, and Parker Counties.
- Groundwater provides all municipal water use in Cooke County and the majority of the municipal use in Fannin, Freestone, Grayson, Parker, and Wise Counties.

Figure 1.10
Historical Source of Supply in Region C

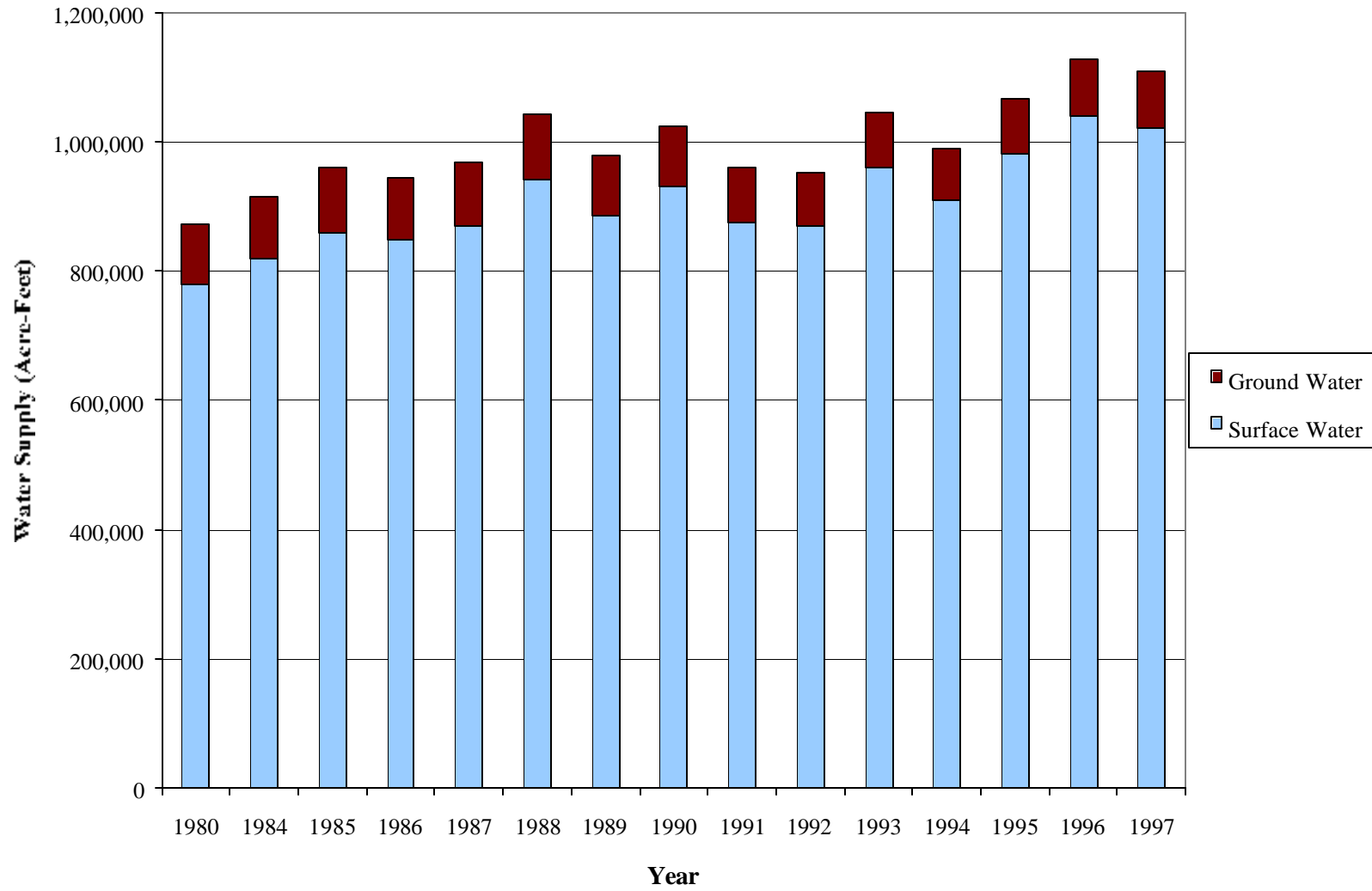


Table 1.9
Sources of Water Supply by County by Category in 1997 for Region C
 - Values in Acre-Feet -

County	Water Type	Municipal	Manufacturing	Steam Electric	Irrigation	Mining	Livestock	Total
Collin	Ground	2,756	228	2	0	0	109	3,095
	Surface	86,458	1,604	1,659	93	341	981	91,136
	Total	89,214	1,832	1,661	93	341	1,090	94,231
Cooke	Ground	5,660	159	0	288	52	991	7,150
	Surface	0	0	0	156	237	991	1,384
	Total	5,660	159	0	444	289	1,982	8,534
Dallas	Ground	2,058	730	0	474	1,385	60	4,707
	Surface	448,041	27,845	11,802	843	1,605	538	490,674
	Total	450,099	28,575	11,802	1,317	2,990	598	495,381
Denton	Ground	10,054	65	0	472	49	868	11,508
	Surface	53,471	821	122	0	90	868	55,372
	Total	63,525	886	122	472	139	1,736	66,880
Ellis	Ground	4,260	2,175	0	23	90	131	6,679
	Surface	10,885	1,421	0	207	0	1,176	13,689
	Total	15,145	3,596	0	230	90	1,307	20,368
Fannin	Ground	2,161	295	282	2,096	0	120	4,954
	Surface	1,899	50	4,685	942	161	1,069	8,806
	Total	4,060	345	4,967	3,038	161	1,189	13,760
Freestone	Ground	2,226	0	95	17	37	521	2,896
	Surface	146	0	11,452	0	170	782	12,550
	Total	2,372	0	11,547	17	207	1,303	15,446
Grayson	Ground	8,945	3,472	0	2,810	815	103	16,145
	Surface	6,725	3,075	0	702	243	920	11,665
	Total	15,670	6,547	0	3,512	1,058	1,023	27,810
Henderson ^b	Ground	2,194	22	0	20	466	497	3,199
	Surface	5,219	71	797	9	165	331	6,592
	Total	7,413	93	797	29	631	828	9,791
Jack	Ground	406	0	0	4	63	92	565
	Surface	642	0	0	0	370	822	1,834
	Total	1,048	0	0	4	433	914	2,399
Kaufman	Ground	199	0	0	1	0	111	311
	Surface	8,083	641	0	134	75	1,001	9,934
	Total	8,282	641	0	135	75	1,112	10,245

Table 1.9, Continued

County	Water Type	Municipal	Manufacturing	Steam Electric	Irrigation	Mining	Livestock	Total
Navarro	Ground	143	1	0	0	89	119	352
	Surface	7,949	1,165	0	0	0	1,074	10,188
	Total	8,092	1,166	0	0	89	1,193	10,540
Parker	Ground	5,609	22	0	82	55	131	5,899
	Surface	4,523	548	126	306	20	1,178	6,701
	Total	10,132	570	126	388	75	1,309	12,600
Rockwall	Ground	146	0	0	0	0	10	156
	Surface	6,140	17	0	0	33	91	6,281
	Total	6,286	17	0	0	33	101	6,437
Tarrant	Ground	14,461	839	3	21	0	423	15,747
	Surface	234,716	27,870	4,648	119	103	423	267,879
	Total	249,177	28,709	4,651	140	103	846	283,626
Wise	Ground	3,278	12	0	272	259	833	4,654
	Surface	2,551	5,900	0	360	16,310	833	25,954
	Total	5,829	5,912	0	632	16,569	1,666	30,608
Region C	Ground	64,556	8,020	382	6,580	3,360	5,119	88,017
	Surface	877,448	71,028	35,291	3,871	19,923	13,078	1,020,639
	Total	942,004	79,048	35,673	10,451	23,283	18,197	1,108,656

Notes: a. Data are from the Texas Water Development Board ⁽⁹⁾.
 b. Data for Henderson County include only the part of the county in Region C.

- Dallas and Tarrant Counties have 74 percent of the municipal water use in the region.
- Tarrant and Dallas Counties have 72 percent of the industrial water use in the region.
- Dallas and Freestone Counties have 65 percent of the steam electric power water use in the region.
- Fannin and Grayson Counties have 63 percent of the irrigation use in the region.
- Wise County has 71 percent of the mining use in the region.
- Livestock use is widely spread throughout the region.

Surface Water Sources

Table 1.10 lists the amount of surface water rights by TNRCC water rights category for each county in Region C⁽¹⁰⁾. Most of the surface water supply in Region C comes from major

Table 1.10
Surface Water Rights by County

County	Permitted Surface Water Diversions (Acre-Feet per Year)					
	Municipal	Industrial	Irrigation	Mining	Other	Total
Collin	100,000	4,000	3,920		23	107,943
Cooke	5,000		203			5,203
Dallas	171,085	19,806	12,260	100	1,531	204,782
Denton	1,392,700	10,300	6,416	3	391	1,409,810
Ellis	17,316	226	1,087		1	18,630
Fannin	5,462	10,140	15,626			31,228
Freestone	205,675	16,787	2,868	115	116	225,561
Grayson	130,580	14,004	1,990	100		146,674
Henderson ^b	172,700	21,178	5,074			198,952
Jack	1,487		341			1,828
Kaufman	6,000		807			6,807
Navarro	36,880	1,460	2,966		70	41,376
Parker	7,625	60,045	2,388			70,058
Rockwall			250			250
Tarrant	302,700	24,830	8,325	1,105	1,874	338,834
Wise	5,000		3,715	10,062		18,777
Total	2,560,210	182,776	68,236	11,485	4,006	2,826,713

- Notes:
- a. Data are from TNRCC water rights list ⁽¹⁰⁾.
 - b. Data for Henderson County include only the part of the county in Region C.
 - c. TNRCC does not have a separate category for steam electric rights. They are included in the industrial category.

reservoirs. Table 1.11 lists the permitted diversions, the actual 1996 diversions, and the estimated reliable supply from major reservoirs (over 5,000 acre-feet of conservation storage) in the region. For many of the reservoirs in the region, permitted diversions are significantly greater than the reliable supply. In planning to meet future needs, it is important to limit assumed availability to the reliable supply. Reliable supply is the supply that would be available in a drought of record condition. The reliable supplies shown in Table 1.11 are the lesser amount of the firm yield or the existing water rights.

Another major source of supply in Region C is surface water imported from other regions. Table 1.12 lists currently permitted imports of water to Region C from other regions. (No

Table 1.11
Water Rights, Diversion and Yield for Major Reservoirs

Reservoir	County(ies)	Water Right Number(s)^t	Permitted Conservation Storageⁿ (Acre -Feet)	Permitted Diversionⁿ (Acre -Feet/Year)	1996 Use^o (Acre -Feet)	Reliable Supply^q (Acre -Feet/Year)
Moss	Cooke	4881	23,210	4,500	0	4,500 ^a
Texoma	Grayson, Cooke	4898, 2006, 4900, 4901, 5003	2,733,000	145,400	44,752	145,400 ^j
Randell	Grayson	4901	5,400	5,280	5,350 ⁱ	5,280 ^a
Valley	Fannin, Grayson	4900	15,000	10,000	9,996	N/A ^m
Bonham	Fannin	4925	13,000	5,340	1,577	5,340
Coffee Mill	Fannin	4915	8,000	0	0	0 ^j (Recreation)
Kiowa	Cooke	2334A	7,000	0	0	0 ^j (Recreation)
Ray Roberts	Denton, Cooke, Grayson	2335A, 2455A	799,600	799,600	90,155	110,000 ^a
Lost Creek	Jack	3313A	11,961	1,397	589	1,397 ^p
Bridgeport	Wise, Jack	3808A	387,000	15,000 ^e	3,019	15,000 ^w
Lewisville	Denton	2348, 2456	618,400	598,900	148,612	110,800 ^a
Lavon	Collin	2410C	380,000	130,957 ^h	179,108	104,000 ^{a,l}
Weatherford	Parker	3356	19,470	5,220 ^b	2,845	2,000 ^a
Grapevine	Tarrant, Denton	2362, 2363, 2458B	161,250	161,250	47,024	23,100 ^c
Eagle Mountain	Tarrant, Wise	3809	210,000	159,600 ⁱ	75,150 ^r	86,600 ^{c,k}
Worth	Tarrant	3340	38,124	13,298	0 ^s	0 ^k
Benbrook	Tarrant	5157A	72,500	72,000	4,650	9,800 ^a
Arlington	Tarrant	3391	45,710	23,120	13,000	7,050 ^a
Joe Pool	Dallas, Tarrant	3404B	176,900	17,000	6,860	16,900 ^a
Mountain Creek	Dallas	3408	22,840	6,400	4,577 ^u	N/A ^m
North	Dallas	2365	17,100	1,000 ^v	1,796 ^u	0 ^d
White Rock	Dallas	2461	21,345	8,703	1,738	N/A ^m
Ray Hubbard	Dallas, Kaufman, Rockwall	2462C, 2462D, 2462E	490,000	89,700	80,525	63,100 ^a
Terrell	Kaufman	4972	8,712	6,000	3,594	1,650 ^a
Bardwell	Ellis	5021A	54,900	14,729 ⁱ	4,976	9,600
Waxahachie	Ellis	5018	13,500	3,570	1,757	2,400 ^a
Cedar Creek	Henderson, Kaufman	4976A	678,900	175,000	45,251	175,000 ^c

Table 1.11, Continued

Reservoir	County(ies)	Water Right Number(s) ^t	Permitted Conservation Storage ⁿ (Acre -Feet)	Permitted Diversion ⁿ (Acre - Feet/Year)	1996 Use ^o (Acre -Feet)	Reliable Supply ^q (Acre - Feet/Year)
Forest Grove	Henderson	4983	20,038	9,500 ^g	805 ^u	N/A ^m
Trinidad	Henderson	4970	6,200	4,000	4,000	4,000 ^c
Navarro Mills	Navarro	4992	63,300	19,400	6,236	19,400 ^j
Halbert	Navarro	5030	7,357	4,003	2,238	600 ^a
Richland-Chambers	Freestone, Navarro	5030, 5035A	1,135,000	223,650	119,594	223,650 ^c
Fairfield	Freestone	5040	50,600	14,150	0	N/A ^m
Mineral Wells	Parker	4039	7,065	2,520	0	1,500 ^a
Total				2,735,187	980,167	1,161,137

- Notes:
- a. Reliable supply for these reservoirs is from 1997 *Water for Texas* ⁽¹¹⁾.
 - b. Diversion does not include 59,400 acre-feet per year of non-consumptive industrial use.
 - c. Reliable supply is from computations by Freese and Nichols.
 - d. Reliable supply depends on water purchased from Dallas.
 - e. Release of 78,000 acre-feet per year for diversion and use from Eagle Mountain Lake is also authorized.
 - f. Permitted diversion includes water released from Lake Bridgeport.
 - g. Permitted diversion does not include non-consumptive use.
 - h. Permitted diversion includes reuse of up to 26,957 acre-feet per year of return flows.
 - i. Permitted diversion includes reuse of up to 5,129 acre-feet per year of return flows.
 - j. Reliable supply is limited to permitted diversion.
 - k. Eagle Mountain Lake reliable supply is the total for Lake Bridgeport, Eagle Mountain Lake, and Lake Worth.
 - l. Reliable supply does not include reuse.
 - m. Reliable supplies are not readily available for these projects.
 - n. Permitted conservation storage and permitted diversions are from TNRCC permits ⁽¹²⁾.
 - o. 1996 use is from TNRCC ⁽¹³⁾ and TWDB records ⁽⁹⁾. Tarrant Regional Water District records show somewhat different diversions for Bridgeport, Eagle Mountain, Benbrook, Cedar Creek and Richland-Chambers.
 - p. Reliable supply is from HDR ⁽¹⁴⁾.
 - q. Reliable supply is the lesser of firm yield and permitted diversion.
 - r. Includes Eagle Mountain Lake Bridgeport (non-local), and Lake Worth.
 - s. Included in Eagle Mountain.
 - t. Water right numbers are Certificate of Adjudication numbers. For permits issued since adjudication, they are the application number.
 - u. 1996 use is according to TXU Electric records as reported to TNRCC.
 - v. Additional use (beyond the water right) is based on purchased water.
 - w. Bridgeport local use only.

Table 1.12
Permitted Importation of Water to Region C

Destination	Source	Source Region	Source Basin	Destination Basin	Permitted Amount (Acre-Feet/Year)	Raw or Treated	Status
North Texas MWD	Lake Chapman ^b	D	Sulphur	Trinity	54,000	Raw	Operating
Irving	Lake Chapman ^b	D	Sulphur	Trinity	54,000	Raw	Partially Developed
Upper Trinity RWD	Lake Chapman ^b	D	Sulphur	Trinity	16,106	Raw	Partially Developed
Dallas	Lake Tawakoni	D	Sabine	Trinity	190,480	Raw	Operating
Dallas	Lake Fork	D	Sabine	Trinity	120,000	Raw	Not Yet Developed
Dallas	Lake Palestine	I	Neches	Trinity	114,337	Raw	Not Yet Developed
Athens ^c	Lake Athens	I	Neches	Trinity	8,500	Treated	Operating
Terrell	Lake Tawakoni	D	Sabine	Trinity	10,090	Raw	Operating
TXU Big Brown Plant	Lake Livingston ^d	H	Trinity	Trinity	16,000	Raw	Operating

Notes: a. Information is from previous work by Freese and Nichols.

b. Lake Chapman was formerly Cooper Lake.

c. Most of Athens is in the Trinity Basin.

d. Use is an upstream diversion based on Lake Livingston water right. Contract allows 20,000 acre per year, with a maximum of 48,000 acre-feet over 3 years.

special permit is required if importation from another region does not involve interbasin transfers, but all significant imports to Region C except TRA's upstream sale from Lake Livingston currently involve interbasin transfers and thus require interbasin transfer permits.)

Figure I-1 shows the surface water reservoirs that provide these imports. There is also small-scale importation of treated water in parts of the region, where small suppliers purchase water that originates in other regions.

Groundwater Sources

Table 1.13 lists historical groundwater pumping by aquifer for Region C ⁽⁹⁾. Table 1.14 shows the 1997 pumping by county and aquifer ⁽⁹⁾. (Note that the pumping totals do not match use totals given in Tables 9 and 10. The Texas Water Development Board supplied both of these sets of data. The discrepancy is probably due to water that is pumped in one county and used in

Table 1.13
Historical Groundwater Pumping by Aquifer in Region C

Year	Pumping by Aquifer (Acre-Feet)						Total
	Trinity	Woodbine	Carrizo - Wilcox	Nacatoch	Queen City	Undifferentiated/Other	
1980	65,200	12,898	4,745	424	56	1,734	85,057
1984	74,768	13,210	6,470	283	66	1,686	96,483
1985	77,760	16,324	6,579	325	59	1,501	102,548
1986	73,464	13,654	6,317	269	66	1,485	95,255
1987	74,728	14,861	5,716	253	49	1,444	97,051
1988	78,344	13,979	6,697	277	65	1,434	100,796
1989	71,443	14,332	5,328	278	63	1,211	92,655
1990	69,295	13,486	5,305	256	63	1,212	89,617
1991	63,484	13,256	4,998	311	64	1,447	83,560
1992	61,322	14,009	5,266	238	62	1,391	82,288
1993	61,089	16,330	5,526	241	58	1,881	85,125
1994	57,110	13,408	5,808	244	60	4,134	80,764
1995	57,241	15,349	6,117	285	62	4,677	83,731
1996	60,589	14,849	6,464	316	76	4,452	86,746
1997	60,032	15,423	5,873	285	58	3,938	85,609

Note: Data are from the Texas Water Development Board ⁽⁹⁾.

Table 1.14
1997 Groundwater Pumping by County and Aquifer

County	1997 Pumping by Aquifer (Acre-Feet)						Total
	Trinity	Woodbine	Carrizo - Wilcox	Nacatoch	Queen City	Undifferentiated/Other	
Collin	946	1,190				309	2,445
Cooke	7,096						7,096
Dallas	4,018	589				479	5,086
Denton	9,423	1,681					11,104
Ellis	3,871	2,493					6,364
Fannin	526	2,452				2,096	5,074
Freestone			2,872		28	34	2,934
Grayson	9,650	6,866				32	16,548
Henderson ^b			2,933		30	132	3,095
Jack	5					560	565
Kaufman		70		228			298
Navarro		82	68	57		104	311

Table 1.14, Continued

County	1997 Pumping by Aquifer (Acre-Feet)						Total
	Trinity	Woodbine	Carrizo-Wilcox	Nacatoch	Queen City	Undifferentiated/Other	
Parker	5,629					24	5,653
Rockwall						156	156
Tarrant	14,419						14,419
Wise	4,449					12	4,461
Total	60,032	15,423	5,873	285	58	3,938	85,609

Notes: a. Data are from the Texas Water Development Board ⁽⁹⁾.

b. Data for Henderson County include only the part in Region C.

another.) The Trinity aquifer is by far the largest source of groundwater in Region C, providing 70 percent of the total groundwater pumped in 1997. (The Trinity aquifer is sometimes called the Trinity Sands and includes the Antlers, Twin Mountain, Glen Rose, and Paluxy formations⁽¹⁵⁾.) The Woodbine and Carrizo-Wilcox aquifers provided 18 and 7 percent of the 1997 totals, with the Nacatoch and Queen City aquifers providing less than one percent and 5 percent from other and undifferentiated aquifers. Groundwater pumping is highest in Grayson, Tarrant, and Denton Counties. These three counties have 49 percent of the region's total groundwater pumping.

Water Reclamation

Over half of the water used for municipal supply in Region C is discharged as treated effluent from wastewater treatment plants, making wastewater reclamation and reuse a potentially significant source of additional water supply. At present, only a fraction of the region's treated wastewater is actually reclaimed and reused in the region. There are currently a number of water reclamation projects in Region C that reuse treated wastewater as a water source for non-potable uses such as irrigation of golf courses. In addition, there are sizable return flows of treated wastewater upstream from many Region C reservoirs. If the reservoir's water rights exceed its firm yield without return flows, as is the case for many Region C reservoirs, return flows will increase the reliable supply from the reservoir. If the reservoir's water rights do not exceed its firm yield, a water right must be obtained to allow indirect reuse of return flows. Current permits for indirect reuse in Region C include the following:

- Trinity River Authority sells treated wastewater from its Central Wastewater Treatment Plant in Dallas County to the Dallas County Utility and Reclamation District.
- North Texas Municipal Water District has a permit to reuse treated wastewater from its Wilson Creek Wastewater Treatment Plant through redirection from Lake Lavon.
- The Trinity River Authority has permits for future reuse of wastewater returned to the Lake Bardwell watershed from the City of Ennis and the City of Waxahachie.

The largest wastewater treatment plants in Region C discharge into the Trinity River and its tributaries downstream from all Region C reservoirs. Tarrant Regional Water District is currently pursuing a major reuse project that will use a portion of this return flow, the Trinity River Authority has a reuse permit pending before TNRCC for the return flows from its wastewater treatment plants, and Dallas and other Region C suppliers have also considered future reclamation projects. Additional discussion on the reuse of treated wastewater is included below in Section 1.6.

Springs in Region C

There are no springs in Region C that are currently used as a significant source of water supply. Springs were important sources of water supply to Indians and in the initial settlement of the area and had great influence on the initial patterns of settlement. Groundwater development and the resulting water level declines have caused many springs to disappear and greatly diminished the flow from those that remain⁽¹⁶⁾.

The TPWD has identified a number of small to medium-sized springs in Region C⁽¹⁷⁾. Table 1.15 shows the distribution and number of these springs as of 1980. Former springs are springs that have run dry due to groundwater pumping, sedimentation caused by surface erosion, or other causes.

1.5 Water Providers in Region C

Water providers in Region C include regional wholesale suppliers such as river authorities and some water districts, and retail suppliers (cities and towns, water supply corporations, special utility districts, and private water companies.) Cities and towns provide most of the retail water service in Region C, with significant contributions from other types of suppliers.

**Table 1.15
Distribution and Estimated Size of Springs and Seeps**

County	Medium (2.8 – 28 cfs)	Small (0.28 – 2.8 cfs)	Very Small (0.028 – 0.28 cfs)	Seep (Less than 0.028 cfs)	Former
Collin	0	3	10	1	4
Cooke	0	3	9	3	1
Dallas	2	6	2	0	4
Denton	0	3	8	1	1
Ellis	0	0	0	0	1
Fannin	0	3	6	3	1
Grayson	0	2	12	1	1
Parker	0	8	3	2	6
Rockwall	0	0	1	0	2
Tarrant	3	6	1	3	5
Wise	0	7	4	3	2

Note: Data are from Texas Parks and Wildlife Department ⁽¹⁷⁾.

Regional Wholesale Water Suppliers

There are six entities which provide regional water service in Region C and do not serve as retail suppliers: Tarrant Regional Water District, North Texas Municipal Water District, the Trinity River Authority, Upper Trinity Regional Water District, Greater Texoma Utility Authority, and the Dallas County Park Cities Municipal Utility District.

Tarrant Regional Water District (TRWD). Table 1.16 is a list of 1997 sales by the Tarrant Regional Water District, which totaled 258,448 acre-feet. TRWD supplies raw water to customers in Tarrant County and in the vicinity of its reservoirs. TRWD owns and operates Lake Bridgeport, Eagle Mountain Lake, Cedar Creek Lake, and Richland-Chambers Lake. The district's water supply system also includes Lake Arlington (owned by Arlington), Lake Worth (owned by Fort Worth), and Lake Benbrook (owned by the Corps of Engineers, with TRWD holding water rights), as well as a substantial water transmission system. The TRWD system has a current firm yield of slightly less than 500,000 acre-feet per year. In addition to its current customers, the district has commitments for long-term water supply to Weatherford and

Table 1.16
1997 Sales by Tarrant Regional Water District

Customer	Source(s)	1997 Raw Water Sales (Acre -Feet)
Fort Worth	Cedar Creek/Richland-Chambers	78,844
Fort Worth	Eagle Mountain	73,620
Fort Worth	Benbrook	884
Arlington	Cedar Creek/Richland-Chambers	56,337
TRA	Cedar Creek/Richland-Chambers	25,402
TXU Electric	Eagle Mountain	4,073
TXU Electric	Arlington	1,270
Mansfield	Cedar Creek/Richland-Chambers	3,699
Benbrook Water and Sewer Authority	Benbrook	2,601
Azle	Eagle Mountain	1,390
Bridgeport	Bridgeport	1,282
West Cedar Creek MUD	Cedar Creek/Richland-Chambers	1,226
Mabank	Cedar Creek/Richland-Chambers	1,061
East Cedar Creek FWSD	Cedar Creek/Richland-Chambers	1,058
Wise County WSD	Bridgeport	1,046
River Oaks	Eagle Mountain	799
Ridglea Country Club	Benbrook	695
Southwest Water Co.	Cedar Creek/Richland-Chambers	497
Walnut Creek SUD	Bridgeport	467
West County Rural WSC	Bridgeport	339
Community WSC	Eagle Mountain	307
Kemp	Cedar Creek/Richland-Chambers	300
Runaway Bay	Bridgeport	229
Springtown	Eagle Mountain	183
Star Harbor	Cedar Creek	153
Mira Vista Country Club	Benbrook	148
Pinnacle Club	Cedar Creek	130
Cedar Creek Country Club	Cedar Creek	102
Bay Golf Holdings	Bridgeport	101
Trident (Warren Petroleum)	Cedar Creek	72
Texas Industries	Bridgeport	60
Country Day School	Benbrook	46
Shady Oaks Country Club	Eagle Mountain	14
Bill Sisul	Cedar Creek	8
Golf Driving Range	Cedar Creek	2
Trinity Materials	Bridgeport	2
Golf Driving Range	Arlington	1
Total		258,448

Note: Data were provided by the Tarrant Regional Water District.

Benbrook, as well a commitment to supply water for users in Ellis County through the Trinity River Authority.

North Texas Municipal Water District (NTMWD). Table 1.17 is a list of 1997 sales by the North Texas Municipal Water District, which totaled 168,247 acre-feet. NTMWD supplies treated water to customers in suburban communities north and east of Dallas. The district obtains raw water from water rights in Lake Lavon, Lake Texoma, and Chapman Lake, all of which are owned and operated by the Corps of Engineers. The district has a water treatment plant on Lake Lavon, and water from all three reservoirs is blended in Lake Lavon before it is withdrawn and treated. NTMWD's current permitted raw water supply is 270,700 acre-feet per year. In addition to providing treated water, the district also owns and/or operates a number of wastewater treatment plants in Region C.

Trinity River Authority (TRA). The Trinity River Authority serves as a regional supplier through a number of projects in Region C:

- TRA holds water rights in Joe Pool Lake, Navarro Mills Lake, and Bardwell Lake, all owned and operated by the Corps of Engineers. TRA sells raw water from these lakes for use in Region C. (TRA has contracts to sell Joe Pool Lake water to Midlothian, Duncanville, Cedar Hill, and Grand Prairie. Midlothian and Grand Prairie are currently using water from the lake.)
- TRA sells raw water to TXU Electric for use in the Big Brown Steam Electric Station on Lake Fairfield. This water is diverted from the Trinity River under water rights held by TRA in Lake Livingston downstream, in Region H.
- TRA has a regional treated water system in northeast Tarrant County, which uses raw water delivered by the Tarrant Regional Water District system through Lake Arlington.
- TRA has a commitment to sell raw water from the Tarrant Regional Water District to water suppliers in Ellis County in the future and is now selling water to some Ellis County entities.

Table 1.18 lists the 1997 sales by Trinity River Authority in Region C, which totaled 22,217 acre-feet of treated water from the Tarrant County Water Supply System and 15,220 acre-feet of raw water. In addition to its raw and treated water sales, TRA operates a number of regional wastewater treatment projects in Region C.

Upper Trinity Regional Water District (UTRWD). Table 1.19 lists the 1997 water sales by the Upper Trinity Regional Water District, which totaled 3,421 acre-feet. UTRWD operates a regional water supply system in Denton County. The district, which has purchased and resold treated water from other suppliers in the past, began operation of its own water treatment plant

Table 1.17
1997 Sales by North Texas Municipal Water District

Customer	Total Treated Water Sales (Acre-Feet)
Plano	47,141
Garland	33,836
Richardson	24,895
Mesquite	17,616
McKinney	9,176
Allen	6,278
Rowlett	5,642
Frisco	4,282
Rockwall	4,057
Wylie	1,709
Forney	1,484
Sachse	1,076
Kaufman	907
Farmersville	821
Princeton	813
North Collin WSC	724
Kaufman 4-1	708
Fairview	662
Royse City	647
Sunnyvale	625
Lucas	532
Cash WSC	510
Caddo Basin SUD	478
East Fork WSC	463
Murphy	425
Parker	397
Milligan WSC	313
Forney Lake WSC	310
Lavon WSC	307

Table 1.17, Continued

Customer	Total Treated Water Sales (Acre-Feet)
Wylie NE WSC	290
Mt. Zion WSC	263
Gastonia-Scurry WSC	240
Seis Lagos MUD	138
College Mound WSC	132
Nevada WSC	121
Rose Hill WSC	94
Fate	85
Josephine	47
Total	168,247

- Notes:
- a. Data were provided by the North Texas Municipal Water District.
 - b. All sales are from the NTMWD system, which draws water from Lake Lavon, Lake Texoma, and Lake Chapman.

**Table 1.18
1997 Sales by Trinity River Authority**

Customer	1997 Water Sales (Acre-Feet)			Source
	Treated	Raw	Total	
Bedford	6,784		6,784	Tarrant County System (TRWD)
Corsicana		6,323	6,323	Navarro Mills
Eule ss	4,817		4,817	Tarrant County System (TRWD)
North Richland Hills	3,922		3,922	Tarrant County System (TRWD)
Midlothian		3,825	3,825	Joe Pool
Colleyville	3,562		3,562	Tarrant County System (TRWD)
Grapevine	3,132		3,132	Tarrant County System (TRWD)
Ennis		2,643	2,643	Bardwell
TXU Electric ^b		2,039	2,039	Livingston (Trinity River)
Post Oak WSC		257	257	Navarro Mills
Dawson		133	133	Navarro Mills
Total	22,217	15,220	37,437	

- Notes: a. Data are from the Texas Water Development Board ⁽⁹⁾.
- b. Water use would be greater in dry years. For example, 1996 water use was 12,682 acre-feet.

Table 1.19
1997 Sales by the Upper Trinity Regional Water District

Customer	1997 Treated Water Sales (Acre-Feet)
Flower Mound	1,173
Corinth	827
Lake Cities MUA	593
Highland Village	511
Bartonville WSC	196
Argyle WSC	109
Denton County FWSD	12
Total	3,421

on Lake Lewisville in 1998, and 1998 sales were more than double the 1997 level, at 7,684 acre-feet. UTRWD has a contract with the City of Commerce to divert up to 16,106 acre-feet per year of raw water from Lake Chapman in the Sulphur River Basin and is currently working with the City of Irving to develop a delivery system to bring that water to Lake Lewisville. UTRWD also has contracts to buy raw water from Dallas and Denton. In addition to its water supply activities, UTRWD provides regional wastewater treatment services in Denton County.

Dallas County Park Cities Municipal Utility District (PCMUD). Table 1.20 shows the 1997 treated water sales by Dallas County Park Cities Municipal Utility District, which totaled 9,244 acre-feet. PCMUD has a water right to divert 50,000 acre-feet per year from Lake Grapevine, but its share of the firm yield from Lake Grapevine is considerably less than 50,000 acre-feet per year. The district operates a water treatment plant and sells treated water from Lake Grapevine to Highland Park and University Park.

Table 1.20
1997 Sales by Dallas County Park Cities Municipal Utility District

Customer	1997 Treated Water Sales (Acre-Feet)	Source
University Park	5,842	Lake Grapevine
Highland Park	3,402	Lake Grapevine
Total	9,244	

Note: Data are from the Texas Water development Board ⁽⁹⁾

Greater Texoma Utility Authority (GTUA). In 1997, the Greater Texoma Utility Authority provided 7,184 acre-feet of raw water from Lake Texoma to Sherman. GTUA has water rights for 25,000 acre-feet per year from Lake Texoma and sells raw water to Sherman, which operates a desalination and treatment plant. GTUA has water available to sell to other customers. The authority also operated wastewater treatment plants for several communities in the Red River Basin.

Retail Water Suppliers

Cities and towns provide most of the retail water service in Region C, and some cities also serve as wholesale suppliers by selling treated water to other water suppliers. Table 1.21 lists the cities in Region C with over 500 acre-feet of wholesale water sales in 1997. Among cities, Dallas and Fort Worth are by far the largest wholesale water suppliers. Table 1.22 lists all retail suppliers in Region D with over 500 acre-feet of municipal retail sales in 1997.

Major Water Providers

TWDB Senate Bill One regulations require additional data development for “major providers of water for municipal and manufacturing purposes.” TWDB rules state that “the definition of a major water provider will be determined by the RWPG based on the characteristics and needs of the region.” The rules also provide this suggested definition: “A major water provider is an entity which delivers and sells a significant amount of raw or treated water for municipal and/or manufacturing use on a wholesale and/or retail basis. The entity can be public or private (non-profit or for-profit). Examples include municipalities with wholesale customers, river authorities, and water districts.”

There are no implications of designation as a “major water provider” except for the additional data tables required by TWDB. The major water provider data is a different way of grouping water supply information. An entity that is not designated as a major water provider will still be included in the regional water plan. TWDB gave a list of “samples of entities that a RWPG might select as MWPs” for each region. In Region C, the sample entities listed were North Texas Municipal Water District, Tarrant Regional Water District, Trinity River Authority, and Dallas Water Utilities.

**Table 1.21
1997 Wholesale Sales by Cities**

City	1997 Wholesale Sales to Other Suppliers (Acre-Feet)	Major Customers (Over 500 Acre-Feet)
Dallas	148,281	Irving, Carrollton, Grand Prairie, Lewisville, Farmers Branch, De Soto, Flower Mound, Duncanville, Coppell, Addison, Cedar Hill, Lancaster, TXU Electric (North Lake Plant and Lake Hubbard Plant), The Colony, Dallas Co. WCID#6, D/FW Airport, Seagoville, Hutchins, City of Denton
Fort Worth	39,521	North Richland Hills, Hurst, Haltom City, Southlake, Keller, Burleson, Saginaw, Forest Hill, D/FW Airport, White Settlement, Trophy Club MUD#1, Tarrant Co. MUD#1, Richland Hills, Grand Prairie, Crowley, Westover Hills, Naval Air Station
North Richland Hills	3,125	Watauga
Midlothian	2,788	Rockett SUD
Corsicana	2,754	Rice Water Supply and Sewer Corp.
Denton	1,484	Upper Trinity Regional Water District
Rockwall	1,328	R-C-H WSC
McKinney	1,224	North Collin WSC
Mineral Wells	981	
Terrell	931	
Lewisville	905	
Cedar Hill	893	
Mabank	599	
Forney	538	
Keller	513	

Note: Data are from the Texas Water Development Board ⁽⁹⁾.

**Table 1.22
Major Retail Water Suppliers in Region C (More than 500 Acre-Feet in 1997)**

Supplier	Type	Primary County	Other County(ies)	1997 Sales in Acre-Feet				
				Municipal Wholesale	Manu-facturing	Municipal Retail	Other	Total
Dallas	Municipal	Dallas	Collin, Kaufman, Denton, Rockwall	148,281	15,473	274,559	5,563	443,876
Fort Worth	Municipal	Tarrant		39,521	8,639	106,668		154,828
Arlington	Municipal	Tarrant		180	1,918	54,223		56,321
Plano	Municipal	Collin	Denton	15	501	46,628		47,144
Irving	Municipal	Dallas			3,474	38,654		42,128
Garland	Municipal	Dallas		1	2,365	31,355	117	33,838
Richardson	Municipal	Dallas	Collin	133	1,628	23,136		24,897
Carrollton	Municipal	Dallas	Denton		2,026	17,771		19,797
Grand Prairie ^(b)	Municipal	Dallas	Tarrant	22	888	17,225		18,135
Mesquite	Municipal	Dallas			751	16,883		17,634
Denton	Municipal	Denton		1,484	517	14,849	122	16,972
Sherman	Municipal	Grayson		285	5,969	6,335		12,589
Lewisville	Municipal	Denton		905	365	10,610		11,880
North Richland Hills	Municipal	Tarrant		3,125	419	7,483		11,027
Farmers Branch	Municipal	Dallas			949	8,382	21	9,331
McKinney	Municipal	Collin		1,224	462	7,501		9,187
Corsicana	Municipal	Navarro		2,754	648	5,308		8,710
Bedford	Municipal	Tarrant			14	8,259		8,273
Grapevine	Municipal	Tarrant	Dallas	7	8	7,470		7,485
De Soto	Municipal	Dallas		11	48	6,828		6,887
Flower Mound	Municipal	Denton		16				6,720
Euless	Municipal	Tarrant			45	6,563		6,608
Duncanville	Municipal	Dallas		6	64	6,330		6,400
Allen	Municipal	Collin			16	6,274		6,290
Hurst	Municipal	Tarrant			32	6,058		6,090
Coppell	Municipal	Dallas				5,938		5,938
University Park	Municipal	Dallas		35		5,807		5,842
Rowlett	Municipal	Dallas	Rockwall	53	10	5,580		5,643
Addison	Municipal	Dallas			67	5,410		5,477
Haltom City	Municipal	Tarrant		9	62	4,950		5,021
Cedar Hill	Municipal	Dallas		893	118	3,711		4,722
Waxahachie	Municipal	Ellis		374	732	3,501		4,607
Southlake	Municipal	Tarrant	Denton			4,578		4,578
Frisco	Municipal	Collin	Denton	37	222	4,195		4,454
Colleyville	Municipal	Tarrant		82		4,201		4,283
Denison	Municipal	Grayson		405	550	3,224		4,179
Rockwall	Municipal	Rockwall		1,328	13	2,772		4,113
Mansfield	Municipal	Tarrant	Johnson	10	170	3,862		4,042
Benbrook	Municipal	Tarrant		2	2	3,916		3,920
Midlothian	Municipal	Ellis		2,788	206	913		3,907
Terrell	Municipal	Kaufman		931	302	2,577		3,810
Mineral Wells ^(a)	Municipal	Palo Pinto	Parker	981	22	2,753		3,756

Table 1.22, Continued

Supplier	Type	Primary County	Other County(ies)	1997 Sales in Acre-Feet				
				Municipal Wholesale	Manu-facturing	Municipal Retail	Other	Total
Keller	Municipal	Tarrant		513	31	3,155		3,698
Lancaster	Municipal	Dallas			154	3,297		3,451
Weatherford	Municipal	Parker		34	269	3,143		3,446
Highland Park	Municipal	Dallas				3,402		3,402
Gainesville	Municipal	Cooke		73	106	3,021		3,200
Watauga	Municipal	Tarrant				3,111		3,111
Rockett SUD	SUD	Ellis	Dallas	N/A	N/A	N/A	N/A	3,106
The Colony	Municipal	Denton				2,965		2,965
Ennis	Municipal	Ellis		N/A	N/A	N/A	N/A	2,643
Burleson ^(a)	Municipal	Johnson	Tarrant		10	2,539		2,549
Highland Village	Municipal	Denton				2,431		2,431
Athens	Municipal	Henderson		1	84	2,108		2,193
Balch Springs	Municipal	Dallas				2,111		2,111
White Settlement	Municipal	Tarrant				1,990		1,990
Dallas Co. WCID#6	District	Dallas		N/A	N/A	N/A	N/A	2,130
Bonham	Municipal	Fannin	Rockwall	241	50	1,631		1,922
Wylie	Municipal	Collin		37	143	1,570		1,750
Saginaw	Municipal	Tarrant		4	120	1,455		1,579
Seagoville	Municipal	Dallas		482		1,059		1,541
Forney	Municipal	Kaufman		538	327	619		1,484
Azle	Municipal	Tarrant		133		1,260		1,393
Trophy Club	Municipal	Denton	Tarrant			1,381		1,381
Forest Hill	Municipal	Tarrant		1		1,353		1,354
Bridgeport	Municipal	Wise		55	319	968		1,342
West Cedar Creek MUD	District	Henderson		N/A	N/A	N/A	N/A	1,241
Richland Hills	Municipal	Tarrant		2	6	1,209		1,217
East Cedar Creek FWSD	District	Henderson		N/A	N/A	N/A	N/A	1,111
Sachse	Municipal	Dallas	Rockwall			1,049		1,049
Corinth	Municipal	Denton		1		1,047		1,048
Mabank	Municipal	Kaufman	Henderson	599		372		971
Decatur	Municipal	Wise			23	940		963
Gun Barrel City	Municipal	Henderson				944		944
Kaufman	Municipal	Kaufman		318	12	577		907
Crowley	Municipal	Tarrant		4	27	862		893
Trophy Club MUD #1	District	Denton	Tarrant	N/A	N/A	N/A	N/A	846
Lake Worth	Municipal	Tarrant		24		800		824
Farmersville	Municipal	Collin		470		352		822
R-C-H WSC	WSC	Rockwall		N/A	N/A	N/A	N/A	819
Princeton	Municipal	Collin		492		316		808
River Oaks	Municipal	Tarrant		21		778		799
Kennedale	Municipal	Tarrant		14	22	762		798
Tarrant Co. MUD #1	Authority	Tarrant		N/A	N/A	N/A	N/A	743
Glenn Heights	Municipal	Dallas	Ellis	123		614		737
Royse City	Municipal	Rockwall	Collin	226	5	492		723
Briar	Municipal	Wise	Tarrant, Parker			663		663
Fairview	Municipal	Collin		23		639		662

Table 1.22, Continued

Supplier	Type	Primary County	Other County(ies)	1997 Sales in Acre-Feet				
				Municipal Wholesale	Manu-facturing	Municipal Retail	Other	Total
Lake Dallas	Municipal	Denton				662		662
Whitesboro	Municipal	Grayson		14		640		654
Rice Water Supply and Sewer Corp.	WSC	Navarro	Ellis	N/A	N/A	N/A	N/A	651
Sunnyvale	Municipal	Dallas			79	546		625
Hutchins	Municipal	Dallas			13	607		620
Heath	Municipal	Rockwall				616		616
Westover Hills	Municipal	Tarrant		N/A	N/A	N/A	N/A	615
Fairfield	Municipal	Freestone		13		599		612
Everman	Municipal	Tarrant				595		595
Lake Cities MUA	Authority	Denton		N/A	N/A	N/A	N/A	593
Jacksboro	Municipal	Jack		1		567		568
Pantego	Municipal	Tarrant		4		557		561
Naval Air Station	Federal	Dallas	Tarrant	N/A	N/A	N/A	N/A	1,074
College Mound WSC	WSC	Kaufman		N/A	N/A	N/A	N/A	530
Ovilla	Municipal	Ellis	Dallas	3		524		527
Red Oak	Municipal	Ellis		23		478		501

^(a)TWDB lists Mineral Wells and Burleson in Region C, but most of their water use is in Region G.

^(b)Data for Grand Prairie were adjusted based on discussions with the city.

Criteria that might be considered in designating suppliers as major water providers include:

- Amount of wholesale sales
- Number of wholesale customers
- Population served through wholesale sales
- Size of service area
- Percentage of total water demands for an area supplied
- Other

The Region C Water Planning Group has decided to designate all entities with wholesale sales in excess of 20,000 acre-feet per year in Region C as major water providers. The major water providers in Region C are Dallas Water Utilities, Tarrant Regional Water District, North Texas Municipal Water District, Fort Worth, and the Trinity River Authority. As other suppliers reach 20,000 acre-feet per year in wholesale sales, they can be added to the list of major water providers. Table 1.23 gives some basic data on the suppliers designated as major water providers in Region C.

Table 1.23
Major Water Providers in Region C

Wholesale Provider	1997 Wholesale Sales (Acre-Feet)			Number of Wholesale Customers		
	Raw	Treated	Total	Cities	Water Suppliers	Others
Tarrant Regional WD	258,448	0	258,448	12	11	16
North Texas MWD	0	168,247	168,247	23	14	1
Dallas	13,324	148,281	161,605	17	4	2
Fort Worth	427	39,521	39,948	18	2	4
Trinity RA	15,220	22,217	37,437	8	2	1

1.6 Pre-Existing Plans for Water Supply Development

Previous Water Supply Planning in Region C

Appendix B is a list of previous water-related plans and reports for Region C. The region has a long history of successful local water supply planning and development. When the Senate Bill One planning process began, pre-existing plans for future water supply in Region C included the following:

- Dallas planned to connect its currently unused supplies in Lake Fork Reservoir and Lake Palestine to its system.
- Dallas was engaged in an update of its long-range water supply plan.
- Irving and Upper Trinity Regional Water District were engaged in development of transmission facilities to bring their water supplies from Lake Chapman to Lake Lewisville.
- Tarrant Regional Water District was planning to divert return flows of treated wastewater from the Trinity River into Cedar Creek and Richland-Chambers Lakes to increase the yield of its system.
- Tarrant Regional Water District was planning to develop Lake Tehuacana on Tehuacana Creek or participate in Marvin Nichols I Reservoir on the Sulphur River.
- Several Region C water suppliers were considering the development of water supplies in the Sulphur Basin to the east. Alternatives included George Parkhouse Reservoirs I and II and Marvin Nichols Reservoirs I and II. Development of any of these sites would require a cooperative effort with water suppliers in the vicinity of the reservoirs, which are located in Senate Bill One Region D.

- Other Region C suppliers were planning and developing smaller water supply projects to meet local needs. Examples included Muenster (new reservoir), Wortham (contract with Mexia), and many entities developing additional wells or seeking water supplies from the major water suppliers in the region.

As discussed in Section 1.4, there has been an increasing interest in the reuse of treated wastewater in Region C in recent years. There are several permits for significant indirect reuse projects in the region. In addition to these permitted indirect reuse projects, many of the reservoirs in Region C make indirect reuse of treated wastewater return flows in their watersheds, which increase reservoir yields. Many water suppliers in the area are considering reuse projects. Several applications for indirect reuse are pending with the Texas Natural Resource Conservation Commission, and TNRCC policy on future indirect reuse projects is not yet firmly established. If TNRCC does not allow the development of additional indirect reuse in Region C, current local water supply planning will be disrupted and other sources must be sought. Direct reuse, often for irrigation of golf courses, is also increasing in the region. It is clear that reuse of treated wastewater will remain a significant part of future water planning for Region C.

Most Recent State Water Plan

The most recent state water plan, *Water for Texas*, published in 1997, proposed several water supply projects for Region C⁽¹¹⁾:

- Diversion of Trinity River wastewater return flows from the Fort Worth area into Cedar Creek and Richland-Chambers Lakes to serve Tarrant Regional Water District by 2025.
- Construction of Tehuacana Reservoir on Tehuacana Creek to serve Tarrant Regional Water District by 2050.
- Development of George Parkhouse II Reservoir in the Sulphur River Basin to serve North Texas Municipal Water District by 2015. (This project might also serve Upper Trinity Regional Water District.)
- Reallocation and permitting of the unappropriated share of Texas' portion of Lake Texoma to serve the North Texas Municipal Water District if the Red River Chloride Control Project improves the amount of usable supply from Lake Texoma by 2050.
- Construction of transmission facilities from Lake Fork Reservoir to serve Dallas by 2005.
- Construction of transmission facilities from Lake Palestine to serve Dallas by 2015.

- Construction of the Marvin Nichols I Reservoir to serve Dallas by 2040. (This project might also serve North Texas Municipal Water District, Tarrant Regional Water District, and Upper Trinity Regional Water District).
- Possible reuse by Dallas Water Utilities to supplement existing supplies.
- Development of transmission facilities from Lake Chapman in the Sulphur Basin to serve Irving and Upper Trinity Regional Water District.
- Possible use of Lake Joe Pool to supply additional water to Waxahachie.

Conservation Planning in Region C

For the last several years, the Texas Water Development Board and the Texas Natural Resource Conservation Commission have required the development of conservation plans as a condition for TWDB financing of projects and for TNRCC permitting. Primarily as a result of these requirements, many entities in Region C and around the state have developed conservation and drought contingency plans. These plans have significantly improved the awareness of water conservation in Texas. In projections of water use made in the 1990s, the Texas Water Development Board has assumed significant reductions in per capita municipal use due to the implementation of conservation measures. The biggest assumed reduction is due to the use of low flow plumbing fixtures in all new development and renovation, as currently required by federal and state law. Additional reductions in per capita use were assumed due to reduced outdoor water use, reduced leakage in distribution systems, and other measures. Texas Water Development Board rules for Senate Bill One require that water use projections include savings from conservation.

In addition to its regional planning provisions, Senate Bill One includes a requirement that all holders of existing water rights for more than 10,000 acre-feet per year for irrigation or more than 1,000 acre-feet per year for any other purpose develop and implement a water conservation plan. This will increase the number of water users preparing conservation plans.

Preliminary Assessment of Current Preparations for Drought in Region C

The recent dry summers in 1996 and 1998 placed considerable stress on water suppliers throughout Texas, including Region C. The larger systems in Region C did not have a shortage of supply, but several had problems with delivery of raw water to points of need and with treated water distribution. Many Region C water suppliers have already made or are currently making

improvements to increase delivery of raw and treated water under drought conditions. Some smaller suppliers in Region C faced a shortage of supplies in the recent drought. Most of those entities have moved to address this problem by connecting to a larger supplier or by developing additional supplies on their own.

Most of the conservation plans developed in response to TNRCC and TWDB requirements include a drought contingency plan. In addition to its regional planning provisions, Senate Bill One included a requirement that all public water suppliers and irrigation districts develop and implement a drought contingency plan.

Other Water-Related Programs

In addition to the Senate Bill One regional planning efforts, there are a number of other significant water-related programs that will affect water supply efforts in Region C. Perhaps the most important are Texas Natural Resource Conservation Commission water rights permitting, the Clean Rivers Program, the Clean Water Act, and the Safe Drinking Water Act.

Texas Natural Resource Conservation Commission (TNRCC) Water Rights Permitting. Surface water in Texas is a public resource, and the TNRCC is empowered to grant water rights that allow beneficial use of that resource. Any new surface water supply source will require a water right permit. In recent years, TNRCC has increased its scrutiny of the environmental impacts of water supply projects, and permitting has become more difficult and complex. Among its many other provisions, Senate Bill One set out formal criteria for the permitting of interbasin transfers for water supply. Since many of the major sources of supply that have been considered for Region C involve interbasin transfers, these criteria will be important in Region C planning.

Clean Rivers Program. The Clean Rivers Program is a Texas program, funded and overseen by TNRCC, designed to provide information on water quality issues and to develop plans to resolve water quality problems. The Clean Rivers Program is carried out by local entities. In Region C, the program is carried out by river authorities: the Trinity River Authority in the Trinity Basin, the Red River Authority in the Red Basin, the Brazos River Authority in the Brazos Basin, the Sulphur River Basin Authority in the Sulphur Basin, and the Sabine River Authority in the Sabine Basin.

Clean Water Act. The Clean Water Act is a federal law designed to protect water quality. The parts of the act which have the greatest impact on water supplies are the NPDES permitting process, which covers wastewater treatment plant discharges, and the Section 404 permitting process for dredging and filling in the waters of the United States, which affects reservoir construction. In Texas, the state has recently taken over the NPDES permitting system, which sets the discharge requirements for wastewater treatment plants. The Section 404 permitting process is handled by the Corps of Engineers, and Section 404 permitting is an important step in the development of a new reservoir and is also required for most pipelines and pump stations.

Safe Drinking Water Act (SDWA). The Safe Drinking Water Act is a federal program that regulates drinking water supplies. In recent years, new requirements introduced under the SDWA have required significant changes to water treatment. On-going SDWA initiatives will continue to impact water treatment requirements. Some of the initiatives that may have significant impacts in Region C are the reduction in allowable levels of trihalomethanes in treated water, the requirement for reduction of total organic carbon levels in raw water, and the possible reduced allowable level of arsenic in drinking water.

1.7 Agricultural and Natural Resources in Region C

Wetlands

According to the regulatory definition of the U.S. Army Corps of Engineers⁽¹⁸⁾, wetlands are “. . . areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.” Areas classified as wetlands are often dependent on water from streams and reservoirs. Wetlands provide food and habitat for fish and wildlife, water quality improvement, flood protection, shoreline erosion control, and groundwater exchange, in addition to opportunities for human recreation, education and research.

The Natural Resources Conservation Service (NRCS) has mapped and quantified areas of hydric soils for all but five of the counties in Region C. The agency makes these data available through its local county offices and, in some cases, publishes the acreages of soil series in the soil survey report for the county. Hydric soil is defined as “. . . soil that in its undrained condition is saturated, flooded, or ponded long enough during the growing season to develop

anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation”⁽¹⁹⁾. Thus, the area of hydric soils mapped in a county provides an indication of the potential extent of wetlands in that county. However, as implied in the definition, some areas mapped as hydric soils may not occur as wetlands because the hydrology has been altered to preclude saturation or inundation.

Table 1.24 is a list of acreages of hydric soils for the counties in Region C for which the data are available. The hydric soil areas range from just over one percent of the county area in Collin, Cooke, and Tarrant counties to approximately 24 percent in Henderson County. The acreages of hydric soils listed in Table 1.24 should be considered as an indicator of the relative abundance of wetlands in the counties and not as an absolute quantity. It should also be noted that wetlands are likely to occur in other areas throughout the region as “atypical” or “problem area” wetlands, as defined in the Corps of Engineers’ Wetland Delineation Manual⁽¹⁸⁾.

Endangered or Threatened Species

Table 1.25 lists “species of special concern” identified in Region C counties by the Texas Parks and Wildlife Department (TPWD)⁽²¹⁾ and U.S. Fish and Wildlife Service⁽²²⁾. Species of special concern include species listed as threatened or endangered at the state level and species that have limited range within the state. The TPWD maintains a list of species of special concern in the Texas Biological and Conservation Data System.

Stream Segments with Significant Natural Resources

In each river basin in Texas, the TPWD has identified stream segments classified as having significant natural resources⁽²⁰⁾. Stream segments have been placed on this list because they have been identified by TPWD as having one or more of the following: high water quality, exceptional aquatic life, high aesthetic value, fisheries, spawning areas, unique state holdings, endangered or threatened species, priority bottomland hardwood habitat, wetlands, springs, and pristine areas.

Stream segments that have been classified as having significant natural resources in Region C in the Trinity River Basin include the following⁽²⁰⁾:

Table 1.24

Hydric Soils Mapped by the Natural Resources Conservation Service for the Counties in Region C

County	Total County Acreage (Acres)	Hydric Soil Acreage within County (Acres)	Percent of County (%)
Collin	565,760	8,620	1.52
Cooke	568,320	7,100	1.25
Dallas	577,920	53,570	9.27
Denton	611,200	10,460	1.71
Ellis	608,000	Not Available	
Fannin	574,080	Not Available	
Freestone	574,720	85,855	14.94
Grayson	627,840	29,240	4.66
Henderson*	604,800	142,540	23.57
Jack	588,800	Not Available	
Kaufman	517,760	Not Available	
Navarro	695,680	86,100	12.38
Parker	581,760	35,350	6.08
Rockwall	94,080	Not Available	
Tarrant	574,080	9,410	1.64
Wise	592,000	13,100	2.21

*Note that the values for Henderson County include all of Henderson County, not just the Region C portion.

- High water quality, exceptional aquatic life, and high aesthetic value - Elm Fork of the Trinity River (headwaters to Lake Ray Roberts), West Fork of the Trinity River (Lake Bridgeport tailrace to Eagle Mountain Lake), Big Sandy Creek (Lake Amon G. Carter tailrace to West Fork of the Trinity River), Spring Creek (Dallas County near Garland), and Tenmile Creek (Dallas County).
- Diverse fishery - Tenmile Creek (Dallas County)
- Unique state holdings - Segment 0804 of the Trinity River (below Cedar Creek Lake spillway; significant holding in Region C is Richland Creek Wildlife Management Area).
- Paddlefish stocking area - Trinity River (Lake Ray Hubbard to Lake Livingston).
- Priority bottomland hardwood habitat - Confluence of Buffalo and Linn Creeks in Freestone County.

Stream segments in the Red River Basin in Region C classified as having significant natural resources include the following ⁽²⁰⁾:

**Table 1.25
Species of Special Concern^a**

Species	Federal Status ^b	State Status ^c	Riparian or Wetland Dependent	County														
				Collin	Cooke	Dallas	Denton	Ellis	Fannin	Freestone	Grayson	Henderson	Jack	Kaufman	Navarro	Parker	Rockwall	Tarrant
Bachman's sparrow		T			x													
Henslow's sparrow						x				x	x	x					x	
Western burrowing owl						x						x					x	
Piping plover	LT		X			x	x				x							
Cerulean warbler					x													
Golden-cheeked warbler	LE	E														x		
American peregrine falcon		E		x	x		x	x	x		x		x		x	x	x	x
Arctic peregrine falcon				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
White-faced ibis		T	X										x					
Whooping crane	LE	E	X	x	x	x	x	x		x	x	x	x	x	x	x	x	x
Bald eagle	LT	T	X	x	x	x	x	x	x	x	x		x	x	x		x	
Migrant loggerhead shrike						x		x				x		x				x
Wood stork	E	T	X		x	x	x			x	x	x		x				
Eskimo curlew	LE	E			x										x			x
Interior least tern	LE	E	X	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Black-capped vireo	LE	E				x							x			x		x
Blue sucker		T	X						x		x							
Western sand darter			X		x						x							
Blackside darter		T	X						x									
Paddlefish		T	X								x							
Shovelnose sturgeon		T	X								x							
Red wolf	LE	E						x					x			x		
Gray wolf	LE	E											x					
Black-footed ferret	LE	E			x													
Plains spotted skunk						x				x		x		x				x
Black bear	T/SA	T							x									
Rafinesque's big-eared bat		T								x								
Southeastern myotis			X							x								
Timber/canebrake rattlesnake		T			x	x	x	x		x	x	x		x	x			x
Brazos water snake		T	X													x		
Texas horned lizard		T			x	x	x	x	x	x	x	x	x	x	x		x	x
Houston toad	LE	E	X								x							

Table 1.25, Continued

Species	Federal Status ^b	State Status ^c	Riparian or Wetland Dependent	County															
				Collin	Cooke	Dallas	Denton	Ellis	Fannin	Freestone	Grayson	Henderson	Jack	Kaufman	Navarro	Parker	Rockwall	Tarrant	Wise
Texas garter snake				x		x	x	x		x		x		x	x	x		x	x
Northern scarlet snake		T												x					
Alligator snapping turtle		T	X											x					
Comanche Peak prairie-clover																x			x
Large-fruited sand verbena	LE	E								x									
Navasota ladies' -tresses	LE	E	X							x									
Warnock's coral root						x													
Rough-stem aster			X											x					
Auriculate false foxglove																			x

Notes: a. Information obtained from the Texas Parks and Wildlife Department⁽²¹⁾ and from the U.S. Fish and Wildlife Service⁽²²⁾.
 b. LE is federally listed endangered, LT is federally listed threatened, and T/SA is federally threatened by similarity of appearance.
 c. E is state listed endangered, T is state listed threatened, and “blank” is rare, but with no regulatory listing status

- Pristine area, spring fed, intermittent pools and ripples - North Fish Creek and South Fish Creek in Cooke County.
- Striped bass spawning and migration and unique saltwater springs - Segment 0204 of the Red River (above Lake Texoma).
- Unique community, wetlands - Rock Creek in Cooke County.
- Unique state holdings - Bois d’Arc Creek in Fannin County (Caddo Wildlife Management Area).
- Paddlefish - Segment 0202 of the Red River (below Lake Texoma) and Shawnee Creek in Grayson County.
- Blue Sucker - Segment 0202 of the Red River (below Lake Texoma).

Stream segments in the Brazos River Basin in Region C classified as having significant natural resources include the following:⁽²⁰⁾

- Recreation - Brazos River, Possum Kingdom Dam to Lake Granbury, including the reach in Parker County which is in Region C.
- Striped bass spawning migration and small mouth bass fishery - Brazos River, Possum Kingdom Dam to Granbury, including the reach in Parker County which is in Region C.
- Pristine and historic area - Sanchez Creek in Parker County.

As discussed in Section 6.5, the Texas Parks and Wildlife Department has recommended certain stream segments in Region C for designation as “ecologically unique stream segments.”

Agriculture and Prime Farmland

Table 1.26 gives some basic data on agricultural production in Region C, based on the most recent data available from the U.S. Department of Agriculture (USDA)⁽²³⁾. Region C includes almost 6,000,000 acres in farms and over 2,500,000 acres of cropland. Irrigated agriculture does not play a significant role in Region C, with less than 1 percent of the cropland irrigated. The market value of agricultural products is significant in all Region C counties, with a total value for 1997 of almost \$500,000,000. (Separate data are not available for the portion of Henderson County in Region C, so the USDA data include the entire county.) For the region as a whole, the market value of livestock is almost twice that of crops.

The Natural Resources Conservation Service (NRCS) defines prime farmland as “land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is also available for these uses⁽²⁴⁾.” As part of the National Resources Inventory, the NRCS has identified prime farmland throughout the country. Figure 1.11 shows the distribution of prime farmland in Region C. Each color in Figure 1.11 represents the percentage of the total acreage that is prime farmland of any kind. (There are four categories of prime farmland in the NRCS STATSGO database for Texas: prime farmland, prime farmland if drained, prime farmland if protected from flooding or not frequently flooded during the growing season, and prime farmland if irrigated.) There are large areas of prime farmland in Cooke, Denton, Collin, Tarrant, Dallas, and Ellis Counties. It is evident from Figure 1.11 that prime farmland in Region C tends to be distributed along streams.

Table 1.26
1997 U.S. Department of Agriculture County Data

	Collin	Cooke	Dallas	Denton	Ellis	Fannin	Freestone	Grayson
Farms	1,407	1,487	768	1,782	1,713	1,604	1,205	2,080
Land in Farms (acres)	270,434	478,860	148,862	362,712	425,717	444,661	422,548	417,356
Crop Land (acres)	190,161	188,496	75,289	197,573	255,083	263,906	133,394	244,589
Harvested Crop Land (acres)	122,000	93,816	38,635	114,788	148,012	143,820	35,469	134,852
Irrigated Crop Land (acres)	403	1,520	1,407	773	817	2,020	331	1,953
Market Value (\$1,000)								
Crops	\$22,432	\$6,223	\$16,276	\$12,885	\$24,695	\$17,057	\$1,437	\$15,697
Livestock	\$11,564	\$31,064	\$6,003	\$40,662	\$15,735	\$22,163	\$18,211	\$19,779
Total	\$33,996	\$37,287	\$22,279	\$53,547	\$40,430	\$39,220	\$19,648	\$35,476

	Henderson^b	Jack	Kaufman	Navarro	Parker	Rockwall	Tarrant	Wise	Total
Farms	1,630	730	1,883	1,513	2,301	265	1,048	2,075	23,491
Land in Farms (acres)	367,096	531,787	388,830	516,395	479,807	46,015	184,081	411,737	5,896,898
Crop Land (acres)	155,335	70,778	181,244	236,567	169,855	31,566	70,233	176,755	2,640,824
Harvested Crop Land (acres)	58,000	14,069	75,801	97,192	52,260	18,978	35,278	59,784	1,242,754
Irrigated Crop Land (acres)	846	212	1,261	346	1,200	27	673	795	14,584
Market Value (\$1,000)									
Crops	\$10,105	\$1,022	\$5,239	\$12,526	\$10,779	\$2,009	\$10,547	\$4,351	\$173,280
Livestock	\$19,391	\$15,897	\$23,783	\$21,048	\$33,058	\$1,726	\$10,323	\$29,925	\$320,332
Total	\$29,496	\$16,919	\$29,022	\$33,574	\$43,837	\$3,735	\$20,870	\$34,276	\$493,612

Notes: a. Data are from the U.S. Department of Agriculture ⁽²³⁾.

b. Data for Henderson County are for the entire county.

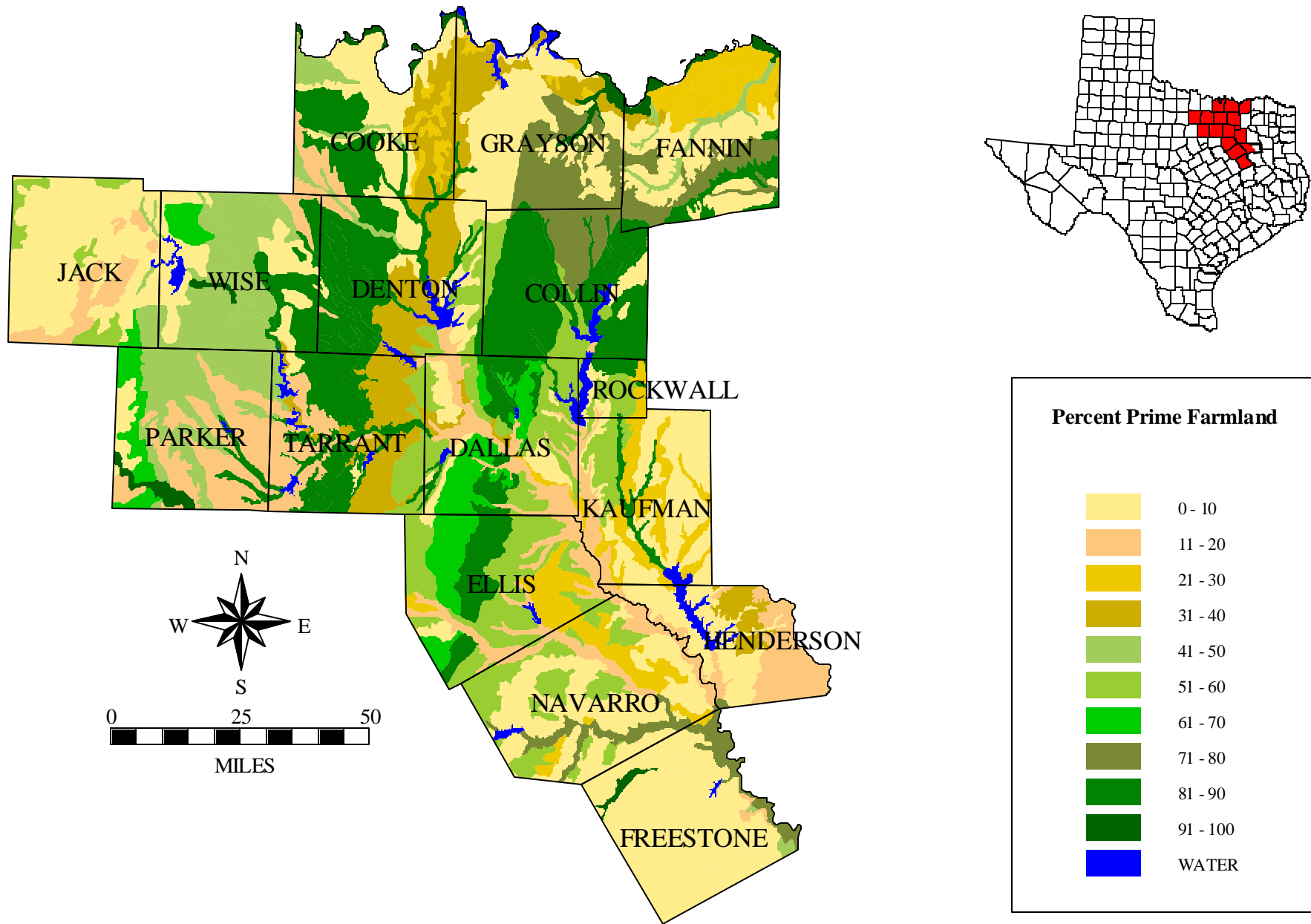


Figure 1.11
Percent Prime Farmland
Region C

There are localized areas of irrigated agriculture in Region C. Table 1.9 shows that 63 percent of the 1997 water use for irrigation in Region C came from groundwater (compared to only 8 percent of total water use from groundwater.) Texas Water Development Board Report 269⁽¹⁵⁾ studied the groundwater in most of Region C (except for Jack and Henderson Counties and part of Navarro County). Most irrigation wells in the study area were scattered over the outcrop areas of the Trinity and the Woodbine aquifers with only a few areas of concentrated activity. The largest concentration of irrigation wells is located on the Woodbine outcrop in an area bounded by western Grayson County, the eastern edge of Cooke County, and the northeastern corner of Denton County. Approximately 80 irrigation wells operated in this region (as of 1982), and several produced as much as 900 gpm. Several smaller irrigation well developments were located in Parker County and Wise County in the Trinity aquifer. There were also irrigation wells in Fannin County producing from the alluvium along the Red River⁽¹⁵⁾.

State and Federal Natural Resource Holdings

The TPWD operates several state parks in Region C: Bonham State Park in Fannin County, Cedar Hill State Park in Dallas County, Eisenhower State Park in Grayson County, Fairfield Lake State Park in Freestone County, Lake Lewisville State Park in Denton County, Lake Mineral Wells State Park in Parker County, Lake Ray Roberts State Park in Denton and Cooke Counties, and Purtis Creek State Park partially in Henderson County. TPWD also operates Caddo Wildlife Management Area in Fannin County, Ray Roberts Wildlife Management Area in Cooke, Denton, and Grayson Counties, Richland Creek Wildlife Management Area in Freestone and Navarro Counties, and Eisenhower State Historic Park in Grayson County.

Federal government natural resource holdings in Region C include the following:

- Parks and other land around all of the Corps of Engineers lakes in the region (Texoma, Ray Roberts, Lewisville, Lavon, Grapevine, Benbrook, Joe Pool, Bardwell, and Navarro Mills)
- Hagerman National Wildlife Refuge on the shore of Lake Texoma in Grayson County
- Caddo National Grasslands in Fannin County
- Lyndon B. Johnson National Grasslands in Wise County.

Oil and Gas Resources

Oil and natural gas fields are significant natural resources in portions of Region C. There is a high density of oil wells in Jack, Wise, Cooke, and Grayson Counties, with a lesser density in

Denton, Parker, Navarro, Henderson, and Kaufman Counties. There is a high density of producing natural gas wells in Freestone, Parker, Jack, and Wise Counties, with a lesser density in Navarro, Henderson, Denton, Cooke, and Grayson Counties. None of the 20 top-producing oil fields in Texas is located in Region C, but two of the 20 top-producing gas fields are in the region ⁽²⁵⁾. The Boonesville field ranked 13th in Texas natural gas production, while the East Newark field ranked 19th. Both gas fields are centered in Wise County.

Lignite Coal Fields

There are some lignite coal resources in Region C ⁽²⁶⁾. Paleozoic rocks with bituminous coal deposits underlie most of Jack County and small portions of Wise and Parker Counties. Near surface (to 200 feet in depth) lignite deposits in the Wilcox Group underlie significant portions of Freestone, Navarro, and Henderson Counties. Deposits of deep basin lignite (200 - 2,000 feet in depth) in rocks of the Wilcox Group underlie a significant portion of Freestone County. The most significant current lignite production in Region C is from the near surface Wilcox Group deposits in Freestone County to supply TU Electric's Big Brown Steam Electric Station on Lake Fairfield.

1.8 Summary of Threats and Constraints to Water Supply in Region C

The most significant potential threats to existing water supplies in Region C are surface water quality concerns, groundwater drawdown, and groundwater quality. Constraints on the development of new supplies include the availability of sites and unappropriated water for new water supply reservoirs and the challenges imposed by environmental concerns and permitting.

Need to Develop Additional Supplies

Most of the water suppliers in Region C will have to develop additional supplies before 2050. The major water suppliers have supplies well in excess of current needs, but they will require additional supplies to meet projected growth. Some smaller water suppliers face a more urgent need for water. Their needs can be addressed by local water supply projects or by purchasing water from a major water supplier.

Surface Water Quality Concerns

The Texas Natural Resource Conservation Commission (TNRCC) published *The State of Texas Water Quality Inventory* in 1996 and 1998^(27, 28). The Water Quality inventories indicate that public water supply use is supported in the stream segments designated for public water supply in Region C. The TNRCC has also established a list of stream segments for which it intends to develop total maximum daily load (TMDL) evaluations to address water quality concerns⁽²⁹⁾. Table 1.27 lists the stream segments in Region C for which TMDL evaluations are proposed and summarizes the water quality concerns to be addressed.

Only a few of the proposed TMDL studies in Region C are due to concerns related to public water supply. Most are due to concerns over aquatic life, contact recreation, and fish consumption. One public water supply concern is the detection of atrazine in treated drinking water originating from several reservoirs in Region C, including Lake Bardwell, Lake Waxahachie, Lake Lavon, Richland-Chambers Lake, and Joe Pool Lake. Atrazine was also found in treated drinking water originating from Lake Tawakoni, which is not in Region C but does provide water for Region C. In each case, the level of atrazine detected was much less than the maximum contaminant level for drinking water. In its Clean Water Act Section 303(d) list, the TNRCC stated as follows for each of these reservoirs: “All water quality measurements currently support use as a public drinking water supply; however, atrazine concentrations in finished drinking water indicate contamination of source water and represent a threat to future use⁽²⁹⁾.” To address this concern, TNRCC has assigned a high priority to development of total maximum daily load (TMDL) evaluations for these watersheds.

Other potential water quality concerns that might affect public water supplies in Region C include nutrient levels in water supply reservoirs, excessive total organic carbon (TOC) levels in source waters, dissolved solids in some reaches, and arsenic. Most of the water supply reservoirs in Region C are experiencing increasing discharges of treated wastewater in their watersheds. To date, this has not presented a problem for public water supplies, but increased amounts of wastewater and greater nutrient loads may lead to concerns about eutrophication in some lakes. Figure 1.12 shows municipal wastewater treatment plants in Region C with over 1 mgd of permitted discharge. Most of the largest plants are on the Trinity River in the Dallas-Fort Worth Metroplex and do not discharge into the watershed of any Region C reservoir. However, there

are significant permitted discharges upstream from many reservoirs in the region, and return flows are tending to increase with time.

**Table 1.27
Total Maximum Daily Load (TMDL) Studies Proposed for Region C**

Segment		Basin	Priority	Concern is for					Description
#	Name			Public Supply	General	Aquatic Life	Contact Recreation	Fish Consumption	
507	Lake Tawakoni	Sabine	Medium	x					All water quality measurements support use as public water supply, but atrazine has been detected at low levels in treated water.
804	Trinity River- Cedar Creek Spillway to Lake Livingston	Trinity	Low/Underway			x	x		Average lead concentration exceeds aquatic life chronic exposure level (out of Region C). Bacteria sometimes exceed contact recreation level in upper 25 miles.
805	Trinity River- Elm Fork to Cedar Creek Spillway	Trinity	Low/Underway				x	x	Bacteria sometimes exceed contact recreation level. Fish consumption not supported in upper 19 miles due to chlordane in fish tissue.
806	West Fork Trinity River- Lake Worth Dam to Village Creek	Trinity	Low/Underway				x	x	Bacteria sometimes exceed contact recreation level in a 17 mile stretch. Fish consumption not supported in lower 12 miles due to chlordane in fish tissue.
806A	Fosdic Lake	Trinity	Medium					x	Fish consumption not supported due to chlordane, dieldrin, DDE, and PCBs in fish tissue.
806B	Echo Lake	Trinity	Medium					x	Fish consumption not supported due to PCBs in fish tissue.
810	West Fork Trinity River- Lake Bridgeport to Eagle Mountain Lake	Trinity	Low				x		Bacteria sometimes exceed contact recreation level in lower 25 miles.

Table 1.27, Continued

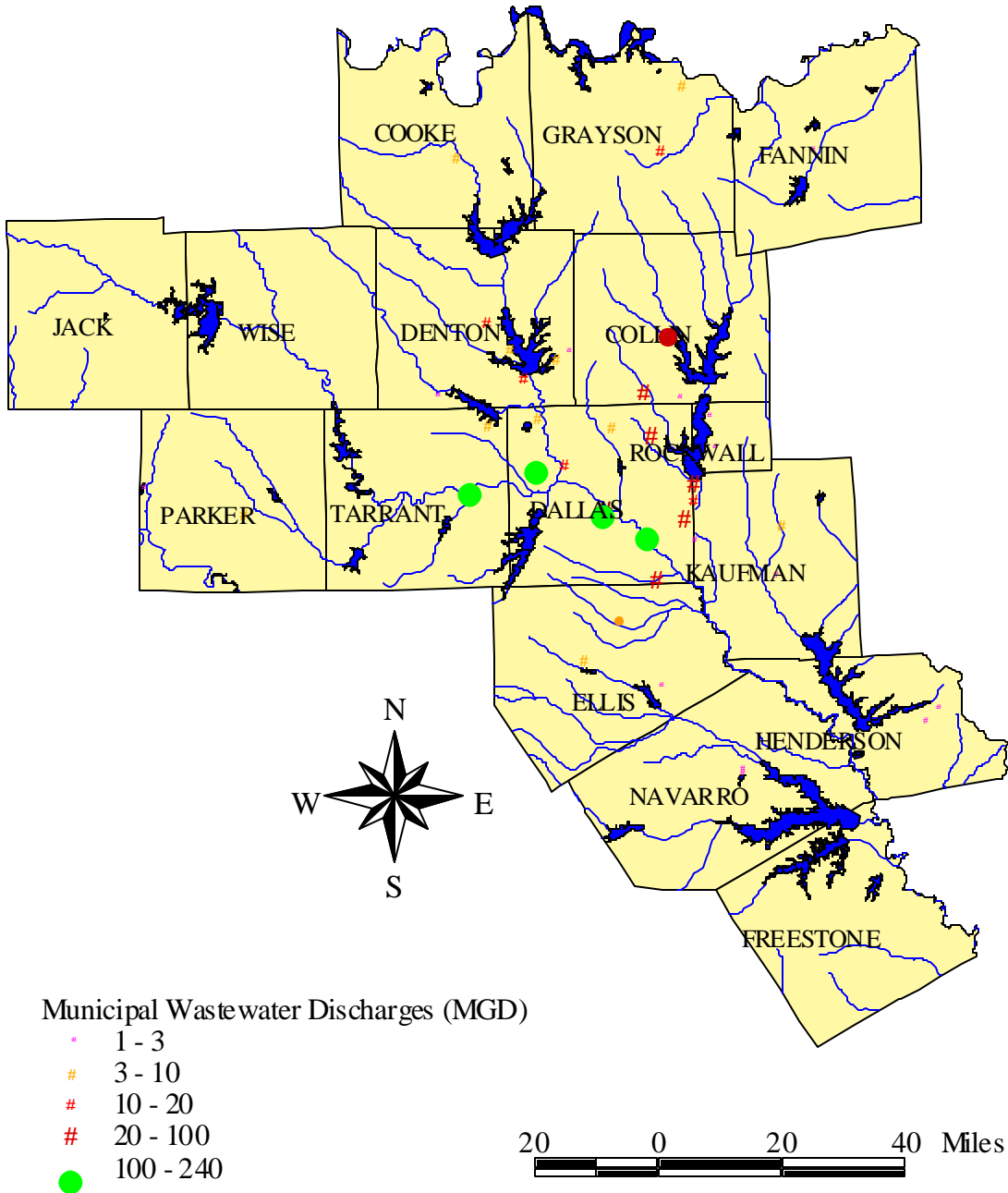
Segment		Basin	Priority	Concern is for					Description
#	Name			Public Supply	General	Aquatic Life	Contact Recreation	Fish Consumption	
812	West Fork Trinity River above Lake Bridgeport	Trinity	Medium		x	x			In lower 25 miles, dissolved oxygen is sometimes lower than the standard to protect aquatic life. In lower 25 miles, average chlorides and total dissolved solids exceed general standard for segment (but not secondary drinking water standards).
815	Lake Bardwell	Trinity	High	x					All water quality measurements support use as public water supply, but atrazine has been detected at low levels in treated water.
816	Lake Waxahachie	Trinity	High	x					All water quality measurements support use as public water supply, but atrazine has been detected at low levels in treated water.
819	East Fork Trinity River below Lake Ray Hubbard	Trinity	Low				x		Bacteria sometimes exceed contact recreation levels in lower 14 miles.
821	Lake Lavon	Trinity	Medium	x					All water quality measurements support use as public water supply, but atrazine has been detected at low levels in treated water.
822	Elm Fork Trinity River below Lake Lewisville	Trinity	Medium			x	x	x	In upper 15 miles, dissolved oxygen is occasionally lower than aquatic life standard. Average lead concentration exceeds aquatic life chronic exposure level and level to protect fish consumption.
824	Elm Fork Trinity River above Ray Roberts Lake	Trinity	Medium			x			In lower 8 miles, average lead concentration exceeds aquatic life chronic exposure level.
829	Clear Fork Trinity River- Lake Benbrook to West Fork Trinity River	Trinity	Medium					x	Fish consumption not supported in lower mile due to chlordane in fish tissue.

Table 1.27, Continued

Segment		Basin	Priority	Concern is for					Description
#	Name			Public Supply	General	Aquatic Life	Contact Recreation	Fish Consumption	
829A	Lake Como	Trinity	Medium					x	Fish consumption not supported due to chlordane, dieldrin, DDE, and PCBs in fish tissue.
831	Clear Fork Trinity River- Lake Weatherford to Benbrook Lake	Trinity	Medium			x			Average lead concentration exceeds aquatic life chronic exposure level in lower 3.3 miles. Dissolved oxygen concentrations are occasionally lower than aquatic life standard in lower 15.7 miles.
833	Clear Fork Trinity River above Lake Weatherford	Trinity	Low			x			Dissolved oxygen standards are occasionally lower than aquatic life standard.
836	Richland-Chambers Lake	Trinity	Medium	x					All water quality measurements support use as public water supply, but atrazine has been detected at low levels in treated water.
838	Joe Pool Lake	Trinity	High	x	x				Average sulfates and total dissolved solids exceed general standards for segment (but not secondary drinking water standards). All water quality measurements support use as public water supply, but atrazine has been detected at low levels in treated water.
841	West Fork Trinity River- Village Creek to Elm Fork	Trinity	Low/ Underway			x	x	x	Bacteria sometimes exceed contact recreation levels in lower 21 miles. Fish consumption not supported in upper 19 miles due to chlordane in fish tissue. Toxicity occasionally exceeds aquatic life standard.
841A	Mountain Creek Lake	Trinity	Medium					x	Fish consumption not supported due to PCBs, chlordane, heptachlor epoxide, dieldrin, DDE, DDD, and DDT in fish tissues.

Notes: a. All information is from TNRCC Section 303(d) list ⁽²⁹⁾.
 b. Lake Tawakoni is outside of Region C, but provides water to Region C.

Figure 23
Wastewater Discharge Points



In December 1998, the U.S. EPA published the *Stage 1 Disinfectants and Disinfection Byproducts (D/DBP) Rule*⁽³⁰⁾, which applies to water systems that treat surface water with a chemical disinfectant. Under certain circumstances, the rule mandates the use of enhanced coagulation to remove total organic carbon (TOC), an indicator of potential disinfection byproduct formation. TRA has commissioned a study to determine the impact of this new rule on Trinity Basin water supplies⁽³¹⁾. Based on TNRCC's 1982-1992 water quality data, 20 Trinity Basin segments in Region C have an average TOC over 6 mg/l. Based on source water TOC and surface water alkalinity, this rule will require TOC reductions of 25 to 40 percent by enhanced coagulation for most Region C water supplies in the Trinity Basin⁽³¹⁾.

Dissolved solids in the Red River and Lake Texoma along the northern boundary of Region C are generally high. Use of Lake Texoma water for public supply requires desalination (Sherman, Red River Authority Tanglewood Estates) or blending with higher quality water (North Texas MWD, Denison). This limits the use of water from the Red River and Lake Texoma for public water supply. The Red River Authority is serving as a local sponsor for the proposed Red River Chloride Control Project, which may serve to improve the quality of Lake Texoma water by diverting saline water before it reaches the lake. Two reaches in Region C – the West Fork of the Trinity River and Joe Pool Lake - show average levels of total dissolved solids and other salts in excess of the current stream standards. In both cases, the levels are below the TNRCC secondary standards for drinking water and should not present a problem for public water supply.

Arsenic is present in several Region C lakes at trace levels, well below the current Safe Drinking Water Act standard of 50 micrograms per liter. The EPA is currently considering adopting a lower standard for arsenic. If the standard is set very low, additional treatment may be required to remove trace levels of arsenic from some supplies.

The Texas Natural Resource Conservation Commission (TNRCC) has the primary responsibility for enforcing state laws against water pollution. Chapter 7 of the Texas Water Code also establishes laws to allow local governments to combat environmental crime, including water pollution. Local enforcement of these laws can supplement the enforcement activities of TNRCC and help protect Texas' water resources.

Groundwater Drawdown

Overdevelopment of aquifers and the resulting decline in water levels poses a threat to small water suppliers and to household water use in rural areas. As water levels decline, the cost of pumping water grows and water quality generally suffers. Wells that go dry must be redrilled to deeper portions of the aquifer. Water level declines have been reported in localized areas in each of the major and minor aquifers in Region C. In particular, the annual pumpage from the Trinity and the Nacatoch aquifers is estimated to be greater than the annual recharge ⁽¹⁵⁾. Concern about groundwater drawdown is likely to prevent any substantial increase in groundwater use in Region C and may require conversion to surface water in some areas.

Groundwater Quality

Figure 1.7 shows the major aquifers in Region C, the Trinity aquifer and the Carrizo-Wilcox aquifer. Figure 1.8 shows the minor aquifers in Region C, which are the Woodbine aquifer, the Nacatoch aquifer, and the Queen City aquifer. Water quality in the Trinity aquifer is acceptable for most municipal and industrial purposes ^(15, 32). However, in some areas, natural concentrations of arsenic, fluoride, nitrate, chloride, iron, manganese, sulfate, and total dissolved solids in excess of either primary or secondary drinking water standards can be found. Water on the outcrop tends to be harder with relatively high iron concentration. Downdip, water tends to be softer, with concentrations of TDS, chlorides, and sulfates higher than on the outcrop. Groundwater contamination from man-made sources is found in localized areas. Texas Water Development Board Report 269 reported contaminated water in wells located between Springtown in Parker County and Decatur in Wise County ⁽¹⁵⁾. The apparent source of the contamination was improperly completed oil and gas wells. Other potential contaminant sources (agricultural practices, abandoned wells, septic systems, etc.) are known to exist on the Trinity outcrop, but existing data are insufficient to quantify their impact on the aquifer ⁽³²⁾.

Water from the Carrizo-Wilcox aquifer is fresh to slightly saline. In the outcrop, the water is hard and low in TDS ⁽³³⁾. In the downdip, the water is softer, with a higher temperature and higher TDS concentrations ⁽³³⁾. Hydrogen sulfide and methane may be found in localized areas⁽³³⁾. In much of the northeastern part of the aquifer, water is

excessively corrosive and has a high iron content⁽³³⁾. In this area, the groundwater may also have high concentrations of TDS, sulfate, and chloride. Some of these sites may be mineralized due to waters passing through lignite deposits, especially in the case of high sulfate⁽³³⁾. Another cause may be the historic practice of storing oil field brines in unlined surface storage pits⁽³³⁾. In Freestone County, excessive iron concentration may be a problem; a well recently completed by the City of Fairfield contained water with a high iron concentration⁽³⁴⁾. Excessive iron concentrations can be removed by treatment.

Water quality in the layers of the Woodbine aquifer used for public water supply is good along the outcrop. Water quality decreases downdip (southeast), with increasing concentrations of sodium, chloride, TDS and bicarbonate. High sulfate and boron concentrations may be found in Tarrant, Dallas, Ellis, and Navarro Counties. Excessive iron concentrations also occur in parts of the Woodbine formation.

The Nacatoch and Queen City aquifers provide very little water in Region C. Available data indicate that the quality of the Nacatoch in this area is acceptable for most uses. Water quality data on the Queen City aquifer in Region C are very limited.

1.9 *Water-Related Threats to Agricultural and Natural Resources in Region C*

Water-related threats to agricultural and natural resources in Region C include changes to natural flow conditions, water quality concerns, and inundation of land due to reservoir development. In general, there are few significant water-related threats to agricultural resources in Region C due to the limited use of water for agricultural purposes. Water-related threats to natural resources are more significant.

Changes to Natural Flow Conditions

Reservoir development, groundwater drawdown, and return flows of treated wastewater have greatly altered natural flow patterns in Region C. Springflows in Region C have diminished, and many springs have dried up because of groundwater development and the resulting drawdown. This has reduced reliable flows for many tributary streams. Reservoir development also changes natural hydrology, diminishing flood flows and capturing low flows. (Some reservoirs provide steady flows in downstream reaches due to releases to empty flood control storage or meet permit requirements.) Downstream from the Dallas-Fort

Worth Metroplex, baseflows on the Trinity River have been greatly increased due to return flows of treated wastewater. It is unlikely that future changes to flow conditions in Region C will be as dramatic as those that have already occurred. If additional reservoirs are developed, they will be required to make low flow releases to maintain downstream stream conditions, which was often not required in the past. It is likely that return flows from the Dallas-Fort Worth area will continue to increase, thus increasing flows in the Trinity River. On balance, this will probably enhance habitat in this reach.

Water Quality Concerns

Table 1.27 lists a number of reaches in which TNRCC has documented concerns over water quality impacts to aquatic life or fish consumption. In general, these concerns are due to excessively low dissolved oxygen levels or to levels of lead, pesticides, or other pollutants that can harm aquatic life or present a threat to humans eating fish in which these compounds tend to accumulate. Two total maximum daily load (TMDL) studies are currently underway in the Trinity – one examining the effects of low levels of lead and the other examining the pesticide chlordane. TMDL studies on other concerns will follow over the next few years.

Inundation Due to Reservoir Development

At various times, a number of new reservoirs have been considered for development in Region C, including:

- Tehuacana Reservoir on Tehuacana Creek in Freestone County.
- Tennessee Colony Reservoir on the main stem of the Trinity River in Freestone, Navarro, Henderson, and Anderson Counties.
- Roanoke Reservoir on Denton Creek in Denton County.
- Italy Reservoir on Chambers Creek in Ellis and Navarro Counties.
- Emhouse Reservoir at the confluence of Chambers and Waxahachie Creeks in Ellis and Navarro Counties.
- Upper Red Oak Reservoir and Lower Red Oak Reservoir on Red Oak Creek in Ellis County.
- Bear Creek Reservoir on Bear Creek in Ellis County.
- New Bonham Reservoir on Bois d'Arc Creek in Fannin County.

At this time, Tehuacana Reservoir and New Bonham Reservoir seem to be the most promising of these projects. The impacts of a new reservoir on natural resources include the

inundation of habitat, often including wetlands and bottomland hardwoods, and changes to downstream flow patterns. Depending on the location, a reservoir may also inundate prime farmland. The impacts of specific projects depend on the location, the mitigation, and the operation of the projects.